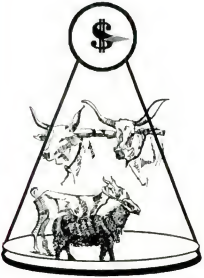
ILRI Proceedings

Economic valuation of animal genetic resources

Proceedings of an FAO/ILRI Workshop held at FAO Headquarters, Rome, Italy, 15–17 March 1999



Food and Agriculture Organization of the United Nations

International Livestock Research Institute

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Contents

Introduction

Food and agriculture are produced under many quite different production circumstances to sustain humankind. The ptoduction circumstances vary in the amount and nature of production inputs and of outputs demanded. They also commonly vary in exhibiting various stress factors, such as food and water shortages, disease and parasites, temperature extremes and so on. These stress factors impact over time on those biological resources in the production system which, through the utilisation of system inputs, are responsible for consistently providing the products on which human beings depend. These biological resources are the microbes, the plants and the animals.

The majority of agricultural production environments world-wide incorporate the use of both plant and animal species, the result being a broader portfolio of system inputs and of outputs, and more robust production over time.

The range of outputs provided by the animal component of these food and agriculture systems is commonly diverse, varying from draft for cultivation, irrigation and harvesting of crops, and for transport; to fibre and leather goods; to manure for fuel and fertiliser; to serving as a credit source particularly in bad seasons; to weed control and spreading of labour inputs throughout the year; as well as in the direct production of milk, meat and eggs for human food. Further, variation in the types of animal used enables the production of different combinations of products and of the same products but of differing quality, to suit local community needs.

All inputs and outputs must be costed, rather than simply what appears to be the most important output; otherwise policy development and decision-making will be distorted. The total value of the many contribution of animals to food and agriculture production has been estimated by the Food and Agriculture Organization of the United Nations (FAO) to be between 30% and 40% of the total value of food and agricultural production. Beyond this again, animals make further important contributions to the culture of many peoples.

With 1 in 6 of the world's human population currently experiencing food insecurity, the number of human beings to increase by at least one-third within the next human generation, and the now quite limited potential for expanding further the area of land used for food and agriculture production, all production environments must continue to be used and both output and output per unit of input must be substantially increased over time.

Fundamentally, it is the genetic composition of the plants and animals which are used for food and agriculture production that enables them to differ in the number, types and quantities of inputs they utilise, in the number, types and quantities of outputs produced; and in the environmental circumstances they tolerate and under which they are most productive.

Further, this genetic composition has continuity over time. Without further inputs it is expressed in sequential generations of offspring; so the genetic benefits and losses made in the varieties or breeds of today are also reaped by future human generations, the inter-generational impact of genetic resources.

The Convention on Biological Diversity has now been ratified by some 180 countries, and the benefit sharing objective of the CBD is now being negotiated to enable full implementation of the convention. The benefit sharing process would be facilitated if the market value of farm genetic resources represented their real value to the community over time.

As production environments, including markets, change in space and over time so does the interest of farmers in utilising particular genetic resources. Perhaps as few as a third of all current breeds of livestock in the world should be used and developed. However, changing a particular breed to meet new conditions takes time. Consequently, the characterisation and conservation of particular breeds which are currently not of strong interest to farming communities may be the most cost-effective approach, rather than allowing unique genes and particularly unique combinations of genes in these breeds to erode to the point of loss. Again, it would be helpful to know the real value of these populations at risk, or at least because financial resources are limiting to know their comparative value so scarce funds can be first invested in conserving those likely to be of greatest future value.

In addition, the signals for breed development must be clear, to enable adequate response to the food and agriculture production imperatives. Apparently, this has not been so for many production circumstances for much of this century. FAO and member countries must be concerned with the differential, if any, between farmers' choice and society's valuation of diversity. Only if this point can be convincingly made is there a case for public sector involvement.

Whilst methodologies for estimating the immediate value of genetic material and, in a broader context, of livestock production system interventions, are reasonably well developed, methodologies for determining to what extent market values of genetic resources predict the real value of genetic resources are less well developed. In this respect, the panel of experts on the development of the global strategy for the management of animal genetic resources has observed that better understanding economic policies and values of animal genetic resources is crucial to implementing the global strategy.

This workshop is being supported jointly by the International Livestock Research Institute (ILRI) and FAO to provide expert guidance on what needs to be done by ILRI and by FAO, under their respective mandates, to guide countries to value their animal genetic resources and to understand how policies may distort markets, subsidising some systems food and agricultural development; thereby assisting countries in their priority setting and action formulation.

On behalf of both Dr Fitzhugh, the Director General of ILRI, and myself, I wish you a most productive workshop.

J. Phelan
Service Chief, AGAP and
Acting Director, Animal Production and Health Division, FAO

Foreword

The International Livestock Research Institute (ILRI) and the Food and Agriculture Organization of the United Nations (FAO) jointly planned this workshop on economic valuation of farm animal genetic resources (AnGR). The purpose of the workshop was to initiate economic analysis of the values of AnGR and to review the impact of policies and programmes concerning AnGR.

This document has two main sections. The first section contains the synthesis report of the workshop. The second section contains several papers which were presented by a number of participants and provided the basis for the workshop deliberations. The schedule of the workshop and the list of participants are included at the end of the document.

Participants were provided with some background reference material before the workshop. There has been very little research done on AnGR values. Most research completed to date has focused on plant genetic material. The following book provides up to date material on plant genetic values:

Evenson R.E., Gollin D. and Santaniello V. (eds). 1998. *Agricultural Values of Plant Genetic Resources*. CAB (Commonwealth Agricultural Bureaux) International, Wallingford, UK by arrangement with FAO and Center for International Studies on Economic Growth, Tor Vergata University, Rome. (ISBN 0 85199 295).

Some economic research has been completed on animal genetics:

Weller J. I. 1994. *Economic Aspects of Animal Breeding*. Chapman and Hall, London, UK.

In addition, a recent conference volume contains many important papers linking animal genetic resources and sustainable development:

Animal Genetic Resources and Sustainable Development. 1998. Proceedings of the 6th World Congress on Genetics Applied to Livestock Production, Armidale, Australia, 11–16 January 1998. Volume 28. International Committee for World Congresses on Genetics Applied to Livestock Production, Armidale, Australia.

K. Hammond from FAO and J.E.O. Rege from ILRI were the principal organisers of the conference. R. Laing and R. Mendelsohn served as rapporteurs.

The workshop was partially funded by USAID through the USAID– Linkages Program for collaboration with US Universities and Research Institutes programme, and by FAO.

R. Mendelsohn
Yale University

Comment on the AnGR valuation problem

H. Steinfeld
FAO–AGAD, Rome, Italy

Let me briefly react to Robert Mendelsohn's 'early thoughts' which you passed on to me. Clearly, this is taking shape. Let me just throw in some ideas from the side.

What is the purpose of the valuation? Clearly, the purpose is to determine the 'real' or 'fair' value of genetic material and diversity. In the case of market failures, market prices will be different from the value that society attaches to genetic resources and diversity.

The first step, thus, is to ascertain whether market failures exist. As with all natural resources, market failures are tied to temporal or spatial externalities. Quite obviously, time horizons differ between the shorter perspective of individuals and that of society. Likewise, the farmer usually is only concerned with the immediate production environment and less with damages/benefits occurring as a result of his/her actions elsewhere. The starting point, hence, is to identify the type and extent of these market failures. Looking at externalities at a more aggregate level, there is ample evidence that production systems based on a narrow genetic base (industrial systems) have more opportunities to generate externalities (pollution) than production systems which are richer in genetic diversity that tend to be more self-contained and have more immediate feedback.

In the case of animal genetic resources (AnGR), markets may assign improper values because of imperfect information, particularly when it comes to assessing future value. I understand that disposing of a certain variety of genes may help hedging against future risks or may keep future options open. What is the probability that certain genes actually provide disease resistance and environmental adaptation elsewhere? What is the probability that certain genetic traits will ever be needed? Without that information, AnGR and diversity cannot be properly valued. The resultant question is: what kind of information is needed to better assess the value of animal genetic resources and diversity. Presumably, a mixture of breed data, genetic distances, and environmental descriptors, etc.

In addition to market failures, we may have important 'policy failures' that provide disincentives for efficient resource allocation. Some of the policies directly or indirectly affecting breed choice are well intended and conscious of the impact. Others pursue more general social or economic objectives but distort the playing field on which different breeds compete. For example, the important capital subsidies that have been characteristic for the Asian miracle and crisis, have clearly favoured an industrial mode of development, also in the livestock sub-sector. Cheap capital led to investments into commercial units with large economies of scale, coupled with high input use (modifying the production environment to the requirements of exotic breeds) and uniform products. These policy distortions can take many forms: subsidised grain imports, free or subsidised support services (AI), support prices for livestock products. Other examples abound. These policies may have helped to supply affordable and safe animal protein to urban centres, but they clearly have put less-intensive production systems at a disadvantage.

Values 1 through 3 in R. Mendelsohn's note relate to productivity (i.e. the technical efficiency, in this case, of a breed plus associated inputs and technology). Productivity, an output/input relationships tells me what I get out of an animal, in physical and in monetary terms. I think conventional production economics can deal with these questions and there is no need to go into great detail in the workshop.

Likewise, the analysis of 'aesthetic values will be more controversial but the methods are clear' – no need to spend much time on this. In the end, if rich people like animals for the shape of their horns, colour, big eyes or whatever, they will pay for it. The poor will not. This is a side issue.

In summary, I suggest the workshop goes through the following steps:

1. determine the presence and likely extent of market failures affecting the use of animal genetic resources
2. determine to what extent market failures are caused by imperfect information and/or by the differential of individual vs society's interests
3. determine the nature and likely impact of policy failures on AnGR. Assess the nature and extent of trade-offs, (for example between conserving AnGR and supply of cheap animal protein with uniform genotypes in industrial units; these two objectives are often clearly in conflict; opportunity costs come in here)
4. if you factor in the above, is there a difference between market value and 'fair' value? How big is it? What would methods look like that account for market and policy failures? Are these advanced methods likely to change famers' choices?
5. if, through steps 1 through 4, you have built up a sufficient case (do not take it for granted from the onset) you may start thinking about an institutional response to address the problem, in terms of a) establishing feedback mechanisms for market failures, b) improved information base, and c) providing policy options that address the trade-offs (or simply remove the distortion).

Economic valuation of animal genetic resources: A synthesis report of the planning workshop

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Introduction

Food and agriculture are produced under many quite different production circumstances to sustain humankind. The production circumstances vary in the amount and nature of production inputs and of outputs demanded. They also commonly vary in exhibiting various stress factors, such as food and water shortages, disease and parasites, temperature extremes and so on. These stress factors impact over time on those biological resources in the production system which, through the utilisation of system inputs, are responsible for consistently providing the products on which human beings depend.

The majority of agricultural production environments world-wide incorporate the use of both plant and animal species, the result being a broader portfolio of system inputs and of outputs, and more robust production over time. The total value of the many contributions of animals to food and agriculture production has been estimated by the Food and Agriculture Organization of the United Nations (FAO) to be between 30% and 40% of the total value of food and agricultural production. The range of outputs provided by the animal component of these food and agriculture systems is diverse, varying from draft power for cultivation, irrigation and harvesting of crops, and for transport; to fibre and leather goods; to manure for fuel and fertiliser; to serving as a credit source particularly in bad seasons; to weed control and spreading of labour inputs throughout the year; as well as in the direct production of milk, meat and eggs for human food. Further, variation in the types of animal used enables the production of different combinations of products and of the same products but of differing quality, to suit local community needs.

All inputs and outputs must be costed, rather than simply what appears to be the most important output or outputs. If all inputs and outputs are not considered, policy development and decision-making may not be effective in achieving desired outcomes. With one in six of the world's human population currently experiencing food insecurity, the number of human beings to increase by at least one-third within the next human generation, and the now quite limited potential for expanding further the area of land used for food and agriculture production, all production environments must continue to be used and both output and output per unit of input must be substantially increased over time.

Policies and decisions affecting animal genetic resources (AnGR) may be long lasting and could be quite important.

Fundamentally, it is the genetic composition of the plants and animals, which are used for food and agriculture production that enables them to differ in the number, types and quantities of inputs they utilise, in the number, types and quantities of outputs produced; in the environmental circumstances they tolerate, and under which they are the most productive. Furthermore, genetic composition has continuity over time. Without further inputs it is expressed in sequential generations of offspring; so the genetic benefits and losses made in the varieties or breeds of today are also reaped by future human generations. This can be viewed as an inter-generational impact of genetic resources (both the genetic resources and knowledge of their use), an investment to pass on to future human generations.

It is commonly understood that animal genetic resources provide an essential contribution to food and agriculture and that methodologies for estimating the immediate value of genetic material and, in a broader context, of livestock production system interventions, are reasonably well developed. However, methodologies for determining the social values of genetic resources are less well developed. Improved understanding of the market value of animal genetic resources will serve to improve the overall management of these essential resources.

Purpose of the workshop

The workshop was convened from March 15–17, 1999 to provide the essential expert guidance to develop methodologies needed to value animal genetic resources and to understand how policies and programmes may distort markets, affecting decisions regarding the management of animal genetic resources. The workshop was supported by the Food and Agriculture Organization of the United Nations (FAO) and the International Livestock Research Institute (ILRI). The intent was to provide the basis for both organisations on potential priority actions and activities in order to help enhance valuation efforts of animal genetic resources. A list of workshop participants is annexed.

In planning the workshop, it was recognised that the field of valuation of genetic resources as a whole, is not yet well developed. Methodologies for valuing AnGRs have not been properly formulated, case studies applying these methodologies have not been done, and clear guidance to policy makers and technicians involved with the management of these resources is not yet available. Within the animal genetic resources sector, the application of existing valuation methodology is clearly in its infancy. Thus, the workshop was viewed as a significant milestone to:

- advance understanding of the current state of the art of valuation
- begin dialogue among geneticists and economists in order to establish a strategic framework to advance development of valuation in animal genetic resources
- further develop a global strategy for the management of farm animal genetic resources
- establish the extent to which market and policy failures affect the management of animal genetic resources and study how to prevent or reduce these failures, and

- establish work plans for both FAO and ILRI in the field of valuation of animal genetic resources.

Workshop participants were asked to determine:

- what needs to be valued
- what methods could be applied, and
- what could be done now to advance valuation of AnGR to assist countries?

Why value animal genetic resources?

The primary motivation for valuing AnGRs is to assist policy development and management decisions. Many decisions require examining a broad array of possible alternatives and selecting a limited set of options to pursue. In order to make these decisions, one must weigh the costs and the benefits of alternative programmes. **Valuation is critical in developing effective breeding programmes.** For example, a group of farmers or breeders might be able to improve many characteristics of a breed. Which attributes are most important? Should the breeders focus on fecundity, weight gain, or disease resistance? Because economic and ecological conditions vary across the world, there is no single answer to such questions. However, if the breeders knew the right answer for the relevant market, they could more effectively design the genetic programme (return higher net benefits). If breeders knew the value that would be assigned to developing livestock species for particular production systems they could make better decisions on which breeds to utilise for the development intervention. This would also help geneticists design better programmes of sustainable intensification, and it would help decision-makers determine how much funding to allocate for such programmes.

Valuation is critical to conservation. As new varieties/breeds get developed and disseminated across markets, particularly among countries, local breeds become less economically attractive. Farmers consequently get enticed to invest in the most recent and available exotic animal genetic resources and abandon locally adapted breeds. Although these decisions may be perfectly rational from a short-term production viewpoint, it does not consider the value of the locally adapted animal genetic resources as a potential stock of genes or as a source of non-market values (such as cultural or environmental values) in the longer term. Further, the justification for importing the exotic breeds is frequently poorly framed. In the absence of established market prices for the genetic value of locally adapted animal genetic resources, and in the absence of established markets for these other values, policy makers might want to consider publicly funded conservation programmes. However, these programmes could be quite costly raising the question abour which genetic resources to conserve. Understanding farm productivity over time, and the benefits of sustainably developing and conserving breeds would help in designing better conservation programmes.

A third motivation for developing values emanates from the recent interest in **benefit sharing**. The concept of benefit sharing arose from the relationship between the failure to share equitably the benefits of genetic resources and the loss of these resources. If those that

bear the cost and responsibility of conserving genetic resources also share in the benefits of the use and development of these resources, they will have the necessary resources (financial and other) and the motivation to conserve these resources.

Parties to the Convention on Biological Diversity are obligated to develop mutually agreed terms for the equitable sharing of benefits arising from the use of genetic resources. However, measures for the equitable sharing of benefits of genetic resources are relatively poorly developed which could be a significant obstacle to better management of animal genetic resources.

Benefit-sharing mechanisms could include property rights issues and creating alternative forms of payments to compensate for the movement of these genetic resources. However, without an understanding of the real value of animal genetic resources, it is difficult to determine payments. Valuation is critical to benefit sharing. In particular, valuation will be important in determining the actual outcomes of alternative benefit-sharing approaches. FAO's Global Databank for AnGR and the analysis of this as published in the World Watch List for Domestic Animal Diversity shows that developing countries have the majority of the animal genetic resources. However, the economic value of these resources has not been quantified. Valuation would therefore help predict which countries have the most valuable genetic resources. This may have serious implications to alternative benefit-sharing mechanisms.

Valuation would also help determine which alternative approaches to improving livestock is best for each country and for each production environment. Valuation would help countries determine the best strategy for developing their AnGR resources for example, using exotic animal genetic resources, or developing locally adapted animal genetic resource, or using both types of resources. Valuation would also help determine the roles and responsibilities of various stakeholders in the management of animal genetic resources, for example, the related roles of policy makers, breeders and farmers.

What should be valued?

Because there are a host of decisions required for AnGR management, there are several values that must be addressed. Designing breeding programmes directed at food security, profit and environment sustainability, conservation programmes, and trading programmes all require some unique information. In addition, decisions affecting AnGR have various implications. In these cases, it is important to value all critical outcomes of decisions that affect AnGR. Of course, which outcomes are critical depends upon values, so there is a certain amount of circularity in this justification. It is necessary to stress the importance of identifying and valuing critical outcomes because valuation is expensive and it would be ineffective to spend scarce valuation resources on outcomes that are trivial. Decision-makers should consequently request values for any outcome if it is likely the valuation of that outcome will affect which choice is preferred. For example, the choice of a breed of cattle for a common pasture may not have any sizeable environmental outcome because all the choices would affect the environment in a similar way. In such a case, it would not be important to value the environment. However, a similar decision in a place with both high

input and pastoral operations might result in farmers choosing to raise cattle only using the high input approach. The fact that the decision would affect whether the pastoral area was used or not would have serious environmental implications. This decision could well rest on the environmental values placed on the use of the pastoral land. In this case, the **environmental values** should be measured.

The design of breeding programmes to achieve sustainable intensification of livestock production sometimes requires knowing what relative weight to place on different observable outcomes or traits of breeds and animals. These decisions require **valuing traits**. Although it may turn out that some traits have universal values, quite often breeds will evolve in, hence most suitable, for specific ecosystems, human populations or cultures. It is expected that the value of traits will vary across environments and production systems and require a set of valuation studies to be conducted.

Breeding, conservation and benefit-sharing programmes are highly interested in **valuing specific traits** of breeds. What do the breeds contribute to a country and what would they contribute to other countries if they were traded? There are multiple consequences of introducing a breed, including the economic net value, genetic pool implications, cultural effects, and environmental effects. Depending upon whether these specific issues are relevant, they must be included in the valuation.

Economic values are likely to be very important to all programmes. Economic benefits traditionally justify breeding programmes and are probably perceived as the motivation for benefit sharing. However, economic benefits could as well be important to conservation programmes as well as provide streams of revenue to help support conservation. Specialised activities such as niche markets and recreation-tourism fees are attractive sources of financial support for conservation. Improvements in AnGR are likely to generate economic benefits by improving market product qualities and improving the productivity of animals. The improvement of quality and quality reliability will tend to increase the demand for products (meant in the broad sense). As the demand for products increase, implicitly the value of animals which produce those products is also enhanced. Increases in productivity (output per unit of input) can come from very direct improvements such as increased weight gain or milk production, or improved feed utilisation by animals as well as from improved fecundity, increased disease resistance, and, particularly for lower input production systems, increased longevity. This improvement will shift the supply of products outward allowing farmers to produce more at less cost. Both sets of improvements increase net consumer surplus, which is the ultimate measure of economic impacts. In turn, these net economic values accrue to the two major actors in the market place, farmers (suppliers) and consumers. One important observation concerning the value of genetic improvements is that the primary beneficiary in the long run is often consumers.

Valuation tools

A broad array of valuation tools which economists have used to measure values were considered during the workshop. Most of these tools have never been used to value AnGR so that their application for this purpose is novel. Participants concluded that the extremely

limited experience with these models for valuing AnGR made it difficult to make recommendation of specific techniques to be used over others. Rather, workshop participants recommended that a broad array of tools be tried to determine the best or most suitable model for differing circumstances.

The valuation tools, that the workshop participants considered should be further studied and developed, cover a broad array of issues facing AnGR valuation. The tools have been selected to value breeds, observed traits, and breeding programmes. Since the consequences of these choices are multifaceted, the values must cover a broad range of effects including the valuation of economic effects, cultural services, and environmental effects. Because economic issues are anticipated to be of the greatest concern, several tools measure economic effects. The tools that have been identified include hedonic methods, aggregate market analysis, cross-sectional household studies, cross-sectional farm studies, contingent valuation (survey methods), genetic programme evaluation, and animal farm models. Each of the methods has different strengths and weaknesses.

The hedonic method is designed to value the observed traits of animals. Historically, it has been applied to value the characteristics of houses, cars, jobs, and recreation. It can be applied to value AnGR in two ways. Hedonic analyses could be done on products heading to market to determine the value of alternative characteristics of those products. For example, one could examine the fat content of milk or meat and measure the value consumers place on that attribute. Alternatively, one could do a hedonic analysis on breeds and animals being selected or purchased by farmers. In this case, attributes that are largely valuable for production would also be included. For example, the weight gain, longevity, and disease resistance of the animal might play a role in the valuation in addition to consumer quality effects. Hedonic analysis requires obtaining data on market sales and the characteristics of the sold animal. By doing analyses across carefully selected markets, one could determine if there is geographic variation in values for example across ecozones or locations affected by disease.

Aggregate market analyses are usually estimated from time series data and possibly panel data. The studies require information concerning aggregate quantities of product sold and price as well as information which might explain variations in both demand and supply. For example, income fluctuations and the prices of substitutes would affect demand. Variation in weather conditions and in prices of inputs might affect supply. From these data, aggregate supply and demand for a product can be estimated. Combined with information about the effectiveness of a genetic programme expanding supply or demand, these functions could then be used to value that change. For example, if a breeding programme would replace the existing herd with one that is 20% more productive, one could determine the value of the 20% improvement. The analysis would also be able to determine what share of these benefits would likely accrue to the farmer and what share to the consumer.

A cross-sectional household study would also try to estimate demand. However, instead of approaching the problem from the top down, a cross-sectional study approaches it from the bottom up. By examining consumers who face different prices because of where they live, one can learn how consumers respond to price. From this information, an aggregate demand function could be formulated for analysis. Assuming a supply function is available

from an alternative source, welfare analysis could then be conducted on alternative scenarios as discussed above. One advantage of this approach is that it may be easier to conduct or find cross-sectional information rather than inter-temporal aggregate data in many developing countries. The approach may have more flexibility. The approach can also explain more of the micro detail and thus provide more confidence that the findings are reasonable.

A **cross-sectional farm** study would estimate supply. Again, by examining farmers facing alternative prices because of their location, one can learn how they respond to price differences. This information could then be used to construct a supply function. Assuming that demand information was available from another source, welfare analysis could be conducted as discussed above. Again, the advantage of this approach over aggregate supply analysis is that data to support a cross-sectional study is more likely to be available in developing countries.

Contingent valuation addresses survey methods of economic values. The survey approach has great flexibility because questions can be variously designed to measure any desired value. The survey approach could also be used to measure the values of observed traits. The survey method can also be used to explore values that are difficult to estimate in any other way. This tool can be applied specifically to explore cultural values and see to what extent non-market values may influence farmers behaviour. Although traditionally contingent valuation is usually used to value resources strictly in terms of money, other forms of measurement can be used. For example, in areas dominated by barter, a common resource instead of money may be used as the metric of value. Similarly, instead of valuing attributes explicitly, farmers might be offered cattle with different qualities and be asked to rank them (contingent ranking) or use pair-wise choices.

The **genetic programme evaluation** is intended to estimate the effectiveness of breeding programmes and the importance of stocks as inputs to those programmes. The evaluation collects information about the costs of a breeding programme, the inputs (breeding stocks), and the outputs. The evaluation attempts to value the outputs and estimate the net return of the breeding programme. If there is sufficient information, we hope to be able to estimate the value of additional inputs and thus determine what a breed contributes to potential future breeds. Similar analyses have been done of the pharmaceutical companies and of the value of one more plant specimen.

The **farm animal model** is a simulation of a representative farmer. The model combines inputs and predicts outputs. With economic variables measuring cost and revenue, the model can determine optimal farm management strategies. Farm models have been built for several species in industrial, high input systems. These models would have to be adapted to developing countries to be used widely. However, farm modeling offers great potential as a tool to measure the value of specific changes such as in litter size, disease resistance, productivity, or a breed change to a specific production system. If the model is coupled with sophisticated market models, the results can be aggregated and used for welfare analysis as well. The major drawback of these models is that they are data intensive and may be expensive to develop and apply.

Recommendations

The workshop generated the following major recommendations. That:

- a research programme on the valuation of AnGRs be created and funded immediately
- a policy and technical programme of work for FAO be created and supported to help develop guidelines for country use in the field of valuation, and
- preliminary valuation issues be included in the state of the world's AnGR report.

The elements of these primary recommendations are detailed in the following section.

A strategy framework for international research in AnGR valuation

Despite the importance of AnGR, reliable data and information on their true values is almost always lacking. Most programmes rely on ad hoc methods to collect values. Many programmes have not determined what values are most appropriate for their region. The absence of good information about these values could well explain many mistakes that have been made in the past. Therefore, it is critical that a research programme be created to provide a useful set of values for AnGR management as rapidly as possible.

A strategic research framework is required to advance understanding of valuation as a management tool with application to AnGR. There are many hurdles that must be overcome to develop a desired set of values. Three critical steps are anticipated:

- first, the potential valuation methodologies must be field-tested to see which ones will work at reasonable cost
- second, a systematic programme of field studies must be conducted so that values will be available in every region in a reasonable amount of time
- third, a set of national studies should be conducted to determine national values of special interest to individual countries.

The case studies should examine each of the seven methodologies that workshop participants identified as potential valuation approaches. There should be a hedonic study, an aggregate demand/supply study, a cross-sectional demand study, a cross-sectional supply study, a survey of opinions, a genetic programme evaluation, and an animal farm model study. These approaches are discussed in the papers presented at the workshop which form part of these proceedings.

The studies should be conducted in more than one location in order to see whether the methods can produce useful information applicable across regions. Workshop participants specifically recommended that the case studies focus on valuing animal resources in developing countries but nonetheless include examples from developed countries as well. These comparisons would help reveal important methodological issues which might arise from applying these approaches in different situations as well as identifying important value differences which might exist across regions.

Finally, several quite different animal species should be examined to ensure that the techniques address all major AnGR resources.

Workshop participants recommended that the case studies be conducted in a systematic fashion so that the research can proceed in a timely fashion over the next two years, and that there be quality control measures so that the methods can be readily compared.

Workshop participants recommended that the case studies be managed by ILRI in co-operation with Yale University and FAO assistance. The research itself, however, should be distributed across a broad set of researchers from around the world. This would facilitate developing regional expertise in valuation, broad participation, and the infusion of new ideas into the programme. The idea would be to assign responsibility for individual projects to different researchers so that experts in each method are included in the group. The group of investigators could then serve as critics and advisers to each other.

The outcome of the case studies will be a set of values that can be used to create some management examples, an evaluation of valuation methodologies, and a set of guidelines for preferred methods.

The second phase of this programme will extend the successful methodology or a combination of them around the world. This will involve carefully conducting studies across enough regions so that every country will have a value that they could reasonably use. The extension would also involve examining the species that were not addressed in the case studies. The extension will require a larger investment as the approaches are applied in more places. The regional extension will also broaden the set of researchers who can conduct valuation. The additional effort will largely be devoted to applying proven method(s) rather than developing them. However, it is still foreseen that additional improvements will be made methodologically at this stage because of insights of the new researchers and because of special problems associated with species and regions.

The result of the regional programme will be to establish a set of values for each region of the world for each species. These values should be sufficiently accurate to serve every country interested in AnGR.

The final phase of the valuation strategy is a set of country studies. Although the regional programme will provide a set of estimates to serve every country, some resources may be so important to a country that they would like to have an estimate of values specific to their own borders. It is envisioned that this final phase would depend on country initiatives and would only be done for selected resources. It is also envisioned that the capacity to do valuation studies will have been thoroughly developed by this point so that there will be sufficient regional expertise for every country to draw on.

Policy and technical issues associated with valuation

The workshop generated a Plan of Action for FAO to address key policy issues surrounding valuation. The participants considered that there were three major topics that FAO should address: facilitating the use of values in AnGR management, understanding and correcting market failures surrounding AnGR resources, and understanding how agricultural and trade policies might impact AnGR management.

Incorporating AnGR values in management

Participants felt that there would be benefits to having FAO develop guidelines demonstrating how AnGR values can be used in making management decisions. In order to support development of these guidelines, FAO could begin by facilitating countries in developing examples illustrating how the results from valuation studies help make important decisions in the field. In addition, FAO should develop a basic framework of guiding principles for use in understanding how to conceive and develop the valuation of AnGR. As part of this overall framework, FAO should help disseminate values as they become known.

Market failure

The workshop participants were concerned that the absence of property rights for AnGR was leading to a market failure. Because breeders could not patent successful outcomes nor could they claim ownership of valuable genes, they would under-invest in genetic research and development. Further, the market would undervalue existing stocks of animals as sources of future genes because there was insufficient financial incentive. Workshop participants considered that issues related to AnGR property rights needed to be examined to determine their implication on the management and valuation of AnGR. The participants recommended that FAO examines alternative regimes for the ownership of specific genetic resource and explore whether alternative institutions could provide a context for improved sale of these resources and thus encourage their conservation. In addition to exploring the implications of alternative solutions to AnGR management, FAO should also explore what effect these arrangements might have on the welfare of countries around the world.

Policy interactions

Workshop participants considered that many policies in agriculture and trade may have incidental effects on AnGR. The participants recommended that FAO examines how alternative policies affect the management of AnGR. FAO should also explore whether alternative policies could lead to more beneficial outcomes for AnGR. For example, policies that subsidise the introduction of exotic breeds, subsidise feed, or subsidise management may all, through encouragement of the introduction of exotics, lead to replacement of indigenous stocks. Similarly, trade policies that limit exports may discourage the development of better breeds in restricted countries. These analyses would help make policy makers aware of AnGR consequences, so that they could take them into account. It was suggested that this policy review include both developed and developing countries.

Guiding principles

Workshop participants were asked to consider developing preliminary guiding principles to advance preparation of guidelines in valuation for country use. The following initial guiding principles were suggested

1. the valuation of AnGR should include not only economic impacts but also non-market effects such as cultural values (existence values) and environmental values
2. most values depend on the context. They will vary by region, market, ecosystem, and production system
3. analysis must consider long-term as well as immediate impacts
4. analysis will help improve decision-making but it cannot eliminate uncertainty nor difficult choices, for example between efficiency and equity
5. valuation studies must be undertaken in an open and transparent way, involving all relevant stakeholders.

Report on the state of the world of animal genetic resources

Workshop participants were informed by FAO of plans to compile a report on the state of the world's AnGR (SOW-AnGR). Based on this discussion, workshop participants recommended that FAO should take advantage of the planned report in order to ask countries preliminary questions about the values they place on alternative aspects of AnGR. For example, countries could provide information about whether economic outcomes, future genetic potential, cultural issues, or environmental concerns are important considerations in developing their AnGR management programmes.

Economic applications in animal genetics and breeding

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Introduction

This paper introduces economic aspects of animal breeding, covered in detail by Weller (1994). The topics considered are economic evaluation of breeding programmes, selection index theory, computing economic values of traits, linear versus non-linear indices, and crossbreeding and heterosis. Lower case **bold type** letters will denote vectors, and upper case **bold type** letters will denote matrices.

Economic evaluation of breeding programmes

Investment in breeding is unique because genetic gains are eternal. They are never used up and never wear out. Genetic gains are cumulative. For example, milk production has been increasing genetically at about 1% per year for the last 20 years.

The major entities with a stake in genetic improvement are farmers; breeders (commercial or co-operative), food processors, consumers, and governments. Although farmers are the main 'consumers' of genetic improvement of agricultural species, they definitely are not the main beneficiaries. Generally, competition among farmers will reduce their profit margin to the minimum. The same will be true of commercial breeders and food processors. Thus, in nearly all cases, the main beneficiaries will be consumers. This complicates economic evaluation of breeding programmes in that neither the suppliers (breeders), nor direct consumers (farmers or food processors) actually gain from genetic improvement.

Despite the considerations given above breeding programmes will be evaluated first in terms of profit (net returns less costs) to the individual farmer. For traditional breeding programmes, costs, and especially costs dependent on the parameters of the breeding programmes, will be small relative to economic gains. Thus, in most cases it will be possible to optimise breeding programmes in terms of expected returns. After initial start-up costs, annual costs will tend to be constant. The main cost elements in traditional breeding programmes are:

1. data recording, which is also useful to farmers for herd management
2. keeping non-productive animals (males) for future breeding

3. progeny testing of candidate males
4. data analysis.

Once a breeding programme is implemented there is an initial lag period. Eventually genetic gains will tend to be linear over time; unless breeding goals are modified. Once a genetic gain is obtained, it is never lost, but its value must be discounted in future years. The total value of a genetic gain, R, to year T is computed as follows:

$$R = V\left(r^1 + r^2 + \ldots + r^T\right) = \sum_{n=0}^{T-1} Vr^n = V\left(1 - r^T\right) / (1 - r),$$

where: V = the value of one year of genetic improvement, d = the discount rate, and r = 1/(1+d). Cumulative gain with a lag of t years until the first gain is realised and a profit horizon to year T is computed as follows:

$$R = \sum_{t=0}^{T} Vr^n - \sum_{t=0}^{t-1} Vr^n = \left[Vr^t\left(1 - r^{T-t+1}\right)\right] / (1 - r)$$

Assume an ongoing breeding programme with an annual genetic gain of V. Without discounting the value of this gain to year T will be a progression of the form: V + 2V +...+TV. Cumulative discounted returns will be a progression of the form:

$$V\left[r^t + 2r^{t+1} + \ldots + (T - t + 1)r^T\right]$$

The sum of the progression, R, total discounted returns from an ongoing breeding programme, is computed as follows (Hill 1971):

$$\left[\frac{(T - t + 1)r^{T+1}}{1 - r} - \frac{r^t - r^{T+1}}{\left(1 - r^2\right)}\right] R = V$$

As an example, genetic gain in dairy cattle is about 100 kg/year, close to 1% of mean production. The marginal value of an additional kg milk is approximately US$ 0.1. Thus, V = US$ 10/cow. Assuming d= 0.08, T = 20 years, and t = 5 years, then R = 32.58V = US$ 325.8/cow. For T = ∞, Hill's equation reduces to: $R = Vr^t / (1 - r)^2$. Using the same parameters values as in the previous example, R = 124.04V = US$ 1240.4/cow.

Unlike genetic gains, costs are not cumulative. Assume an annual cost of C_c. Then total discounted costs, C, to profit horizon T are computed as follows:

$$C = \left[C_c r\left(1 - r^T\right)\right] / (1 - r)$$

Using the same parameter values: C = 9.82C_c. At the break-even point total costs are equal to total gain, that is R = C. Using the same parameter values:

$$32.58V = 9.82C_c$$

$$V = 0.3C_c$$

Assume V = US$ 10/cow, and a population of 100,000 cows (the situation in Israel). Then V = US$ 1,000,000. At the break-even point, V = 0.3C_c. Thus, the break-even value for C_c = US$ 3,300,000. As long as annual costs are US$ 3,300,000, profit will be positive in 20 years. In practice costs are much less, so breeding programmes are very profitable.

New biotechnology, such as multiple ovulation and embryo transfer, or marker-assisted selection can be very costly. Are the costs justified? Assume that genetic gain is increased by 10%. Continuing the previous example, the cumulative net value will be US$ 100,000. Thus, additional annual costs of up to US$ 330,000 can be justified. Several alternatives have been suggested to evaluate alternative breeding programmes:

1. compute aggregate profit with discount rate and profit horizon fixed
2. compute the discount rate required to obtain cumulative profit of zero at profit horizon
3. compute time required until zero profit is reached with a fixed discount rate.

Other studies have attempted to evaluate alternative breeding programmes in a competitive situation, based on change of profit to an individual breeder (Dekkers and Shook 1990). Of course to have any increase in profit, it must be assumed that the competitors do not implement the same changes at the same time.

Linear selection index

Generally the breeding objective consists of several traits, each with specific economic and genetic parameters. How should candidates for selection be ranked to achieve maximum economic gain? If the economic values of all traits are constants, economic gain is maximised by selection based on linear selection index theory (Hazel 1943). For all candidates for selection, the aggregate genotype, H, can be computed as:

$$H = \mathbf{a}'\mathbf{y},$$

where: $\mathbf{a}$ = vector of economic values, and $\mathbf{y}$ = vector of breeding values. The vector a is directly observed, but y cannot be observed. The objective of selection index is to find $I = \mathbf{x}'\mathbf{b}$ that maximises genetic gain in future generations, where $\mathbf{x}$ = vector of records, and $\mathbf{b}$ = vector of index coefficients. $\mathbf{b}$ is computed as follows:

$$\mathbf{b} = \mathbf{P}^{-1}\mathbf{G}\mathbf{a},$$

where: $\mathbf{P}$ = phenotypic variance matrix, and $\mathbf{G}$ = genetic variance matrix. Selection index has many useful properties:

1. mean aggregate genotype of selected individuals is maximum by ranking on $I = \mathbf{x}'\mathbf{b}$, which maximises $r_{H,I}$
2. I minimises $E(H-I_a)^2$, where I_a = any alternative linear index
3. I maximises the probability of correct pair-wise ranking for H
4. selection of parents on I maximises $f(E(\mathbf{x}))$ of progeny, where $f(E(\mathbf{x}))$ = the objective function at the expectation of $\mathbf{x}$
5. I is independent of the selection intensity.

All these properties hold, provided that the economic values of all the traits included in the index are constants. If this is not the case, then no selection criterion is uniformly 'best.'

Linear vs non-linear economic values

In order to compute the economic values of the individual traits, it is necessary to define the objective function. The alternatives that have been suggested are:

1. profit, defined as: income - costs
2. economic efficiency, defined as: income/costs
3. biological efficiency, defined as energy of product/energy of production.

Even if profit is a monotonic function of the economic traits, it will generally be a non-linear function of the trait values. This will be illustrated using the example of Moav (1973) for dairy cattle. Only a single economic trait, milk production is considered, and profit per cow, P_c, is defined as follows:

$$P_c = x(i_m - c_m) - c_f,$$

where: x = milk production per cow, i_m = income per kg milk, c_m = costs of production per kg milk, and c_f = fixed costs per cow. The economic value of x is obtained by the derivative of the profit function with respect to x: $dP_c/dx = i_m - c_m$ = the economic value for milk. In this case the economic value of x is constant, and is independent of x. Now consider profit per kg milk, which is computed by dividing the previous equation by x as follows:

$$P_m = i_m - c_m - c_f / x$$

The derivative of this function is: $dP_f/dx = c_f/x^2$, which is a non-linear function of x.

Although there is no uniformly best solution for ranking candidates for selection if the profit function is non-linear, several alternatives have been suggested:

1. computing derivatives of profit function at current population mean (Goddard 1983)
2. maximising $E(H_s)$ = expectation of aggregate genotype of selected individuals (Goddard 1983)
3. restricted selection indices (Brascamp 1984)
4. maximising f(E(x)) = objective function at the expectation of x in the next generation (Moav and Hill 1966).

Each of these alternatives will be considered. If derivatives are computed and evaluated at the current population mean for the trait values, a will be a vector of constants. Reasonable results are obtained if the objective function is not near an optimum. Goddard (1983) presented the following counter example. If the objective function is: $f(x) = -(x-a)^2$, then $df(x)/dx = -2(x-a)$. This derivative is positive if x<a and negative if x>a.

If E(H) of the selected group is maximised (alternative 2), genetic progress is not maximised. This can be illustrated by the following example (Goddard 1983): the objective function is $f(x) = x^2$, and the mean of x = 0. Individuals furthest from mean will be selected, but the population mean will remain the same, and genetic gain will be zero!

Alternative 3, restricted selection indices, or selection for desired changes, are linear indices that are derived based on the following assumptions: information on economic

values is often vague. However, certain changes are known to be undesirable, for example, decrease in fertility. Therefore, construct the index that yields the desired changes without regard to the actual economic values. Although a reasonable idea, restricted indices are not optimal in any sense.

Moav and Hill (1966) proposed to construct the index that maximises f(E(x)) of the progeny. Even if f(x) is non-linear in **x**, a linear index will always maximise f(E(x)) of the progeny. However, if f(x) is non-linear, then the optimum index is a function of the selection intensity. Moav and Hill (1966) solved for b for any two-trait index. A general solution to maximise f(E(x)) was derived by Pasternak and Weller (1993).

Crossbreeding and heterosis

Often economic value of progeny is increased by crossbreeding among different breeds or strains, as compared to selection within a single line. Moav (1966) defined five types of heterosis:

1. Heterosis of component traits (true overdominance). In plants this is termed 'specific combining ability'
2. Heterosis due to sex-linkage. In mammals a male passes his Y chromosome to his sons. Thus, there is no similarity between sire and son for genes located on the X chromosome
3. Maternal effects. The male contributes only half of the nuclear genetic material. In mammals the female also contributes cytoplasmic genes (mitochondria), a prenatal maternal effect, and a postnatal maternal effect
4. 'Non-linearity' heterosis. This will be explained below
5. Sire–dam heterosis. This is the main justification for crossbreeding in poultry and swine, and will also be explained in detail.

Non-linearity and sire–dam heterosis will be illustrated with the following example (Moav 1966). Assume that pigs are slaughtered at a fixed market weight. Profit per pig, f(x), can then be defined as follows:

$$f(x) = K_1 - k_2 x_2 - k_3 / x_1,$$

where: x_1 = number of pigs weaned per dam, x_2 = age to fixed market weight, and k_1, k_2 and k_3 are constants; x_1 (female fertility) and x_2 (growth rate) are the traits under selection, and are different for different strains. For progeny of a cross between two strains, x_1 is dependent only on the dam, while both parents determine x_2. Therefore, if a sire from strain s is mated to a dam from strain d profit will be:

$$f(x_{sd}) = K_1 - k_2(x_{2s} + x_{2s})/2 - k_3 / x_{1d}$$

However, mean profit of parents, $f(x_m)$, is computed as follows:

$$f(x_m) = K_1 - k_2(x_{2s} + x_{2d})/2 - k_3(x_{1s} + x_{1d})/(2x_{1s}x_{1d})$$

While expected profit of offspring produced by a mating between the two lines, $f(x_o)$, is computed as follows:

$$f(x_0) = K_1 - k_2(x_{2s} + x_{2d}) / 2 - 2k_3 / (x_{1s} + x_{1d})$$

Non-linearity heterosis is defined as $f(x_o) - f(x_m)$, while sire-dam heterosis is defined as $f(x_{sd}) - f(x_m)$. Gains obtained by heterosis are not passed to future generations and are not cumulative. Therefore the nominal value of these gains must be much greater than additive genetic gains to be useful in breeding programmes.

Conclusions

Investment in breeding is unique because genetic gains are eternal and cumulative. Therefore investment in breeding is economically viable even if the nominal annual costs are greater than the nominal annual return. Linear selection is uniformly best if the objective function is a linear function of all traits, but this is rarely the case. There is no uniformly best solution for non-linear objective functions. Any gain obtained by crossbreeding will not be permanent and cumulative, and is therefore worth only a small fraction of the additive genetic gain obtained through selection.

References

Brascamp E.W. 1984. Selection indices with constraints. *Animal Breeding Abstracts* 52:645–654.

Dekkers J.C.M. and Shook G.E. 1990. Economic evaluation of alternative breeding programmes for commercial artificial insemination firms. *Journal of Dairy Science* 73:1902–1919.

Goddard M.E. 1983. Selection indices for non-linear profit functions. *Theoretical and Applied Genetics* 64: 339–344.

Hazel L.N. 1943. The genetic basis for constructing selection indexes. *Genetics* 28:476-490.

Hill W.G. 1971. Investment appraisal for national breeding programmes. *Animal Production* 13: 37–50.

Moav R. 1966. Specialized sire and dam lines. I. Economic evaluation of crossbreeds. *Animal Production* 8: 193–202.

Moav R. 1973. Economic evaluation of genetic differences. In: Moav R. (ed), *Agricultural Genetics: Selected Topics* . John Wiley and Sons, New York, USA. pp. 319–352.

Moav R. and Hill W.G. 1966. Specialized sire and dam lines. IV. Selection within lines. *Animal Production* 8: 375–390.

Pasternak H. and Weller J.I. 1993. Optimum linear indices for non-linear profit functions. *Animal Production* 56: 43–50.

Weller J.I. 1994. *Economic Aspects of Animal Breeding*. Chapman and Hall. London, UK. 244 pp.

Characterisation and conservation of animal genetic resources: What is it about?

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Livestock are an important part of many smallholder farming systems in tropical countries providing not only meat and milk but also power for land cultivation, manure for improving soil fertility and structure and as a source of fuel, and fibre and hides for clothing. They also are a means of investing cash to be realised in times of need.

Farmers around the world use over 4500 breeds or strains of domestic livestock of some 40 or more species. Unfortunately, however, only a handful of these breeds and species account for the vast majority of animal agriculture world-wide. By some accounts, the genetic base of domestic livestock is narrower than that of crops.

Farmers in the tropics have, over the past 10,000 to 12,000 years, selected livestock that are able to live and produce under harsh conditions. The resulting breeds have attributes that include resistance to specific diseases, heat tolerance, ability to use poor-quality feeds and ability to survive on irregular supplies of feed and water. The livelihood–indeed the very survival– of many farmers in developing countries depends on indigenous livestock breeds, or genetic resources. The most rational strategy for conserving livestock breeds is to ensure that they remain a functioning part of the farm production system.

Unfortunately, almost one-third of all the world's livestock breeds are at risk of disappearing. Further erosion of animal diversity will result in loss of options for use in increasing long-term productivity.

Diversity in indigenous tropical breeds

Domesticated livestock and poultry breeds may be broadly divided into specialised and non-specialised breeds or strains. Specialised breeds are those breeds that give high yields of a particular product or set of products or commodities. Among the specialised breeds there are dairy cattle breeds, beef cattle breeds, dual-purpose (dairy and beef) cattle breeds, dairy goats, meat goats, wool sheep, mutton sheep, egg-laying chickens and broiler chickens. Almost all specialised breeds have their origins in developed countries where livestock breeding has been towards specific goals for hundreds of years. Specialised breeds are more genetically uniform than non-specialised breeds. In dairy cattle, for example, elaborate animal evaluations and international movement of germplasm – particularly semen and, more recently, embryos – have resulted in a situation in which, for some breeds such as the Friesian, genetic differences in animals between regions are diminishing.

The genetic diversity within non-specialised breeds of livestock in tropical developing countries is still relatively large, although declining. These populations may be carrying

unidentified genes which could be critical for increasing production or special adaptation in the future.

Genetic erosion of indigenous breeds

The main threat to domestic animal genetic resources in developing countries is crossbreeding with, and/or replacement by, specialised exotic breeds. Increasing human populations and consequent settlement in pastoral areas is also reducing land available for livestock, leading to pressures of animal herders to settle and take up sedentary farming. Neglect arising from commercialisation of agriculture and changes in traditional farming systems threaten the security of some of the least studied populations. Drought and civil conflict have also decimated localised livestock populations, especially in Africa.

Various attempts have been made to develop systems for identifying the level of threat to animal genetic resources. The variables which determine threat categories include population size (especially number of breeding females), reproductive rates, herd/flock sizes, degree of isolation and survival rates. The most elaborate systems for classifying populations into threat categories is that of the Food and Agriculture Organization of the United Nations (FAO). Rege (1999) has applied this framework to identify indigenous African cattle breeds that are at various levels of risk.

Conservation

Globally, animal agriculture depends on only a few animal breeds and species. The mainstream agricultural community remains largely ignorant of the wealth of animal genetic resources potentially available. Unless these resources are conserved, their potential will never be realised and may even be lost for ever.

Without doubt, the most rational and sustainable way to conserve animal genetic resources is to ensure that indigenous breeds remain functional parts of production systems, that is, conservation through use. This is possible only if economically important attributes of indigenous breeds are identified, studied and incorporated in breed improvement programmes. Identification of unique attributes should also increase interest in these genetic resources.

ILRI contributes to conserving animal genetic resources through activities aimed at facilitating the characterisation of indigenous breeds/strains and enhancing their use. The institute is also trying to determine what causes populations to decline; this information will help scientists develop strategies for reducing the likelihood of 'safe' populations becoming endangered in the future and for arresting or reversing declines already in progress. This activity is part of a broader effort aimed at identifying national and regional problems constraining use and improvement of indigenous animal genetic resources and determining how these problems may be solved using existing institutions and available infrastructure.

Adaptive traits of indigenous livestock breeds

The first task for a programme to conserve endangered livestock breeds is to characterise the populations, including a better understanding of adaptive traits, special characters and genetic distinctiveness. This information provides the basis for developing research and development activities for sustainable use of these AnGR. ILRI is developing and maintaining a database of domestic animal diversity, including information on number of breeds or strains found in an area, population sizes and major characteristics of these breeds, as part of the global effort to characterise and conserve livestock biodiversity. This database will be an important source of information for use in research and training programmes and for monitoring trends in distribution and loss of biodiversity in the regions covered. Once their potential is known the indigenous breeds can be better utilised as part of sustainable farming systems.

Characterisation of the adaptive traits of selected African breeds of cattle and small ruminants is part of the ILRI research agenda. ILRI is assessing the N'Dama breed for its tolerance to trypanosomosis, one of the major diseases of tropical livestock in Africa in the tsetse-infested lowlands. Two indigenous breeds of sheep, the Horro and Menz, are being assessed for their performance under challenge from gastro-intestinal parasites. Similar studies to assess variation in resistance to these endoparasites in Red Maasai and Dorper sheep in coastal Kenya have shown that the Red Maasai breed are more resistant to these parasites. Work is in progress to locate the regions of the genomes of N'Dama cattle and Red Maasai sheep at which the genes conferring these adaptations reside and to identify genetic markers to facilitate marker-assisted selection.

In 1995 ILRI embarked on a project using molecular-genetic techniques — genetic fingerprinting — to determine how closely various 'groups' of Africa's cattle breeds are related genetically to each other. The information generated will help animal geneticists and conservationists decide where to start in conserving the genes representing Africa's indigenous cattle populations. The ILRI project is linked with a global project to determine genetic distances between domestic animal species that FAO is leading.

The future of world food production lies in the genes in domesticated crops and livestock and their close wild relatives. The world must act to preserve this heritage for future generations. ILRI is playing its part in this effort.

Objectives

In summary, the objectives of ILRI's programme on AnGR aims to ensure that the diversity of important domesticated animal germplasm in developing countries is safely maintained and made available for research and animal improvement programmes both in the short term and in the long term. This will be achieved by addressing the following specific objectives:

- develop baseline information on indigenous livestock — number of breeds, size and distribution of populations and production environments

- characterise these populations in terms of physical, performance — under traditional and alternative systems of production — and physiological characters, including special adaptive attributes
- determine causes of decline in populations found to be at risk and develop strategies to arrest or reverse such declines
- undertake genetic characterisation, including estimation of genetic distances among populations and quantification of within-species genetic diversity as well as genetic variation in adaptive characteristics in order to facilitate development of rational utilisation and conservation strategies
- develop breeding strategies for incorporating adaptive and other important characteristics into breed improvement programmes
- identify national and regional problems preventing utilisation and improvement of indigenous animal genetic resources and determine how these problems may be solved, in particular how existing institutions may be strengthened for this purpose
- facilitate training of scientists in national programmes to promote their involvement in the management of their AnGR.

Reference

FAO (Food and Agriculture Organization of the United Nations). 1992. FAO Animal Production and Health Paper 104. FAO, Rome, Italy. pp. 14–23.

Rege J.E.O. 1999. *The state of African cattle resources I. Classification framework and identification of threatened and extinct breeds*. Animal Genetic Resources Information 25: (In press).

Economic valuation of farm animal genetic resources

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Introduction

The need to curb the loss of genetic diversity has been argued on biological and ecological bases. Empirical estimation of the economic value of the benefits of biodiversity is still at a rudimentary stage. The rationale and possible methods for estimation of economic benefits are currently being developed and debated. While some progress has been made in evaluating the value of lost crop genetic resources, practically nothing has been done in the area of farm animal genetic resources (AnGR). Yet the challenge here is greater, due to the much smaller pool of global animal genetic resources compared to crops. Most (over 60%) of known AnGR are found in developing countries, where the threat of extinction is greatest. An estimated one-third of the world's AnGR is at risk of being lost forever. This loss of irreplaceable animal diversity reduces options for achieving sustainable agriculture and universal food security. The size of the problem and limited financial resources available for conservation necessitate economic valuation of this diversity so that conservation efforts can be better focused.

Until now, ILRI's research has focused on biological characterisation of animal genetic resources. The outputs of this research – quantification of genetic diversity, identification of genetically unique breeds, and the identification and characterisation of economically important unique attributes – provides a starting point for modeling diversity of animal genetic resources, and constitutes a critical component of the economic valuation process.

Both economic and biological characterisation aim at providing information to facilitate rational conservation, which includes active utilisation as well as preservation. Characterisation should, therefore, include economic valuation of the cost of lost genetic resources and the potential benefits of conserving existing resources, particularly those at risk of extinction. The premise of ILRI's proposed work on economic valuation of AnGR is that economic assessment of the impact of lost biodiversity of animal genetic resources may provide an additional basis for estimating the potential future benefits of conserving animal genetic diversity. Such valuation is also expected to add rationality to the biological arguments for conservation, help identify alternative approaches or options for conservation, and guide research and development activities.

Economic valuation of AnGR: For what?

From the above, economic valuation of AnGR is seen as an important component of overall research and development in support of the short and long-term use of AnGR by

1. providing rational bases for priority setting for
    - breed improvement programmes
    - programmes for conservation (incorporating use) and preservation. (These include provision of bases for allocation of financial resources).
2. prompting action through awareness creation in terms of
    - what benefits and opportunities may have been lost
    - what potential benefits exist for future generations.
3. providing bases for benefit sharing.

Valuation of AnGR: What to value?

The contributions of AnGR that may need to be valued include

- economic traits
- socio-cultural contributions
- scientific contributions
- environmental (ecological) contributions
- aesthetic value.

Valuation of AnGR: What to quantify?

The elements that may need to be quantitatively (or qualitatively) determined in order to assess economic worth of AnGR may include measurement of the economic value of several attributes and/or functions. These include:

1. uniqueness
    - genetic distance of a particular breed/population from other such groups in a country, region, continent, etc
    - rare alleles that may be unique to the particular breed or population
    - genotypic uniqueness encompassing an array of attributes expressed in terms of breed distinctiveness or uniqueness; this is the aggregate of all additive and interactive effects of genes collectively possessed by the breed.
2. economic traits
    - productivity: food, fibre, work, manure, etc

- adaptive attributes, including:
  - disease resistance/tolerance
  - drought tolerance
  - use of low quality feeds.

3. socio-cultural uses
   - store of wealth (in absence of banking systems)
   - prestige
   - dowry payments
   - cementing of relations - e.g. through exchanges, transfers etc
   - cultural ceremonies.
4. use of marginal lands not suited for any other agricultural activity
5. special (unique) products or functions
6. employment of rural populations
7. import substitution (foreign exchange saving function).

Review of AnGR valuation work to date

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Considering the ongoing process of erosion of animal genetic resources (AnGR), among the different economic issues associated with biodiversity conservation policies I will briefly discuss and review the following:

- valuation of AnGRs
- conservation costs
- which options to prevent, stop and reverse processes of breed decline.

Valuation of AnGRs

Choosing what to conserve: Some economic aspects

- In AnGR conservation resources are scarce while needs are great. In order to make proper choices between (and within) breeds, we need a ranking, based on one or more criteria.
- Different criteria for selection of breeds for conservation have been proposed (Ruane 1999):
  - degree of endangerment
  - adaptation to a specific environment (indicators are being developed by FAO)
  - traits of economic importance (today, in the future?)
  - unique traits, breed specific
  - cultural or historical value
  - genetic uniqueness (i.e. the extent to which a breed is different from all others)
  - species a breed belongs to.
- Some open issues related to breed selection
  - some economic value could be considered as an additional criteria
  - how to weight the seven above criteria? Economic values could be introduced as weighting factors?
  - conservation costs (and probability of success) could be added as criteria
  - policies based on economic principles should not be in conflict with biodiversity conservation objectives
  - minimum breed variation to be maintained?

Models of value

- Valuation models are discussed in other papers in these proceedings.
- Almost no work done to date on AnGRs (some work done on Plant Genetic Resources (PGR)). Smith (1984) compared the costs of different conservation programmes of AnGRs in UK to loss of an arbitrary percentage (1%) of the total UK annual livestock production value due to a potential catastrophic event. Assuming that conservation of AnGRs would prevent these losses, conservation costs were easily justifiable.
- Cost-benefit analysis could be of some partial use, e.g. Mitchell et al (1982) made an attempt to measure the value of genetic improvement of pigs in Great Britain, estimating costs and benefits of pig improvement. Similarly, it might be interesting to evaluate the cases of genes of local breeds that were introgressed in commercial populations (e.g. Chinese pig breeds).
- Given the current developments in biotechnology techniques, values might be affected substantially (the debate is still open if values will be enhanced or reduced).

Legal issues

Intellectual property rights (IPR) and farmer rights (FRs) deserve much attention in our context as they can provide, if properly addressed, a useful framework for preservation.

Conservation costs

- Several costs can be associated with conservation of AnGRs. These include costs of programme co-ordination, training, databases, evaluation studies and field conservation. Considering field conservation, because different conservation techniques are available (*in situ*, *ex situ* live, cryoconservation of genetic material and their combinations), it is necessary to compare costs among different techniques.
- The literature on costs of conservation techniques is very scarce; however, some general statements can be made (Gandini and Oldenbroek 1999):
  - in comparing costs of different techniques, conservation objectives should be well defined (e.g. cost of cryconservation with semen can substantially increase if breed re-establishment is the objective)
  - in comparing costs of different techniques, the conservation time horizon should be taken into account
  - within techniques, costs may vary considerably among species because of the differences in efficiency of techniques among species
  - costs are expected to differ significantly among regions and countries

- *in situ* costs strongly depend on the economic competitiveness of the endangered breed, i.e. on the subsidies necessary to compensate for additional costs compared to keeping more productive breeds
- all the literature refers to simulated costs; no data from field projects are available.

Which options to prevent, stop and reverse processes of breed decline?

- In most cases it is likely that local breeds decline because they are not profitable under present market conditions.
- Are options, mechanisms or marketing strategies available to prevent, stop or reverse breed decline, in particular by creating an added value recognised by the market and potentially
  - reduce the number of breeds that need to be conserved
  - reduce conservation costs within breed (moving toward self-sustaining conservation)
  - understand valuation of non-market values (i.e. indirect use values, option values, etc)
  - promote *in situ* conservation, which is the technique able to cover the widest spectrum of conservation objectives
  - counteract the processes of breed decline before populations (and probabilities of success) become too small.
- Several general options have been proposed (FAO 1998; Gandini and Oldenbroek 1999)
  - establishing the economic performance of the breed
  - infrastructures and technical assistance
  - genetic improvement
  - optimisation of the production system
  - developing activities to increase the market value of breed products
  - incentives.

Different options will be appropriate for different regions (different societies give different values to livestock development: food security, environmental concerns, product quality, etc). The three options discussed below are more relevant to the problem of AnGR valuation.

Establishing the economic performance of the breed

- For most local breeds reliable data on performances are not available. In many areas of the world comparisons of performances between crossbred and indigenous breeds have been based on poor experimental designs, which often produce misleading results.

- Knowledge of breed performances is needed for proper economic evaluation of AnGR.
- It is likely that better evaluations of the economic performances of local breeds may change the results of comparisons among local and 'exotic' breeds, i.e. may possibly correct erroneously perceived differences or may identify possible strong points of the local breed.

Developing activities to increase the market value of breed products

Links between products and breeds

- One of the first questions might be: is the relationship between breed and product helpful to diversify the products and then to sell them at higher prices, i.e. to improve the economic profitability of the breed?
- Generally, the control and the enhancement of quality of agricultural products is a combination of the raw materials (e.g. meat or milk) and the processing. Once a certain quality level is achieved, it can be promoted by advertising some desirable elements of the product to the customer. Then, the next question is: can the breed be an element for diversification and grading the product? Can the breed-product link be used as an element in advertising the product? Some recent experiences in Europe (Gandini and Giacomelli 1997) support the approach of a marketing link between products and local breeds. Examples of successful product-breed links also exist outside Europe (personal communication).

Ecological and cultural breed products

- We may consider that in Europe (Gandini and Giacomelli 1997)
  - before the intensification and industrialisation process in the last decades, livestock farming was closely linked to the use of farmland in extensive systems. Most of the areas which are today recognised as natural areas a.. in fact agro-ecosystems created and maintained by farmers and their local breeds. The decline of local breeds and of their production systems is raising concern about the future maintenance of these agro-ecosystems and cultural landscapes;
  - when grazing ceases, bush encroachment follows, which makes it more difficult to use the lands for recreation. Farmers can maintain landscapes of great beauty, rich in culture. Examples in this tespect are the Alpine pastures, which attract large numbers of tourists in summer;
  - the reduction of livestock grazing is known to increase risks associated with natural fires, especially in the Mediterranean regions, and to floods in the Alpine areas;
  - local breeds can be sometimes considered, from a cultural point of view, to be testimonial of the farming civilisation of the specific area (not only in Europe).

- Based on these and similar considerations, several European countries and the EC developed specific agriculture and environment policies, including subsidy systems directed to rural landscape and agro-ecosystems management. However, subsidies are not expected to be available in the long term. This then raises the question of whether developing a market value for the ecological and cultural services from local breeds is possible. Recent experiences allow some optimism:
  - in Southern Europe cheese producers and breed associations have begun to envisage an ecological role for their local breeds;
  - in Austria, some Tyrolean communities and tourism enterprises observed that summer tourists expected the presence of a farming community with their breeds, i.e. availability of local food products, presence of animals and farming culture on tracking areas. In the past few years these tourism businesses have started to subsidise the farmers to avoid the decline of farming activities. In doing so they recognise a market value of the cultural and ecological value of farming;
  - in several parts of Europe horses are recognised as a more appropriate means to harvest wood under rough terrain. This may help the conservation of the original heavy European horses;
  - organic farming recognises a role for local breeds which are adapted to their production environment, are more resistant to diseases, and often naturally farmed following organic principles. Thus, organic farming might provide an additional context for the economic valuation of local breeds.
- The emerging community-based integrated wildlife-livestock production systems in Southern Africa have potential for effective AnGRs valorisation.

Incentives

During the time that is needed to increase the economic profitability of the endangered breed, incentive payments can effectively halt the decline of the breed. Incentives may be necessary to put in operation the options, just described, to improve the economic profitability of the breed.

References

FAO (Food and Agriculture Organization of the United Nations). 1998. *Secondary Guidelines for Development of National Farm Animal Genetic Resources Management Plans: Management of Small Populations at Risk.* FAO, Rome, Italy. 215 pp.

Gandini G. and Giacomelli P. 1997. What economic value for local livestock breeds? 48th Annual Meeting of EAAP. (Abstract)

Gandini G. and Oldenbroek J.K. 1999. Choosing the conservation strategy. In: Oldenbroek J.K. (ed), *Genebanks and the Conservation of Farm Animal Genetic Resources.* ID-DLO, Lelystad, The Netherlands.

Mitchell G., Smith C., Makower M. and Bird P.J.W.N. 1982. An economic appraisal of pig improvement in Great Britain. *Animal Production* 35: 215–24.

Ruane J. 1999. Selecting breeds for conservation. In: Oldenbroek J.K. (ed), *Genebanks and the conservation of farm animal genetic resources*. ID-DLO, Lelystad, The Netherlands.

Smith C. 1984. Estimated costs of genetic conservation of farm animals. In: *Animal Genetic Resources Conservation and Management, Data Banks and Training*. FAO Animal Production and Health Paper 44/1. FAO (Food and Agriculture Organization of the United Nations), Rome, Italy. pp. 21–30.

Management of farm animal genetic resources

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True or false?

Food security can do without animals?

- 1.96 billion people depend on animals daily
- demand for animal products is increasing more rapidly
- animals provide diverse product arrays
- mixed species systems (both plant and animal) are generally more sustainable.

Farm animals: the forgotten side of agriculture.

One super animal breed could meet all needs?

- adapted genetic resources are necessary for sustainable agriculture
- food and agriculture production environments will remain diverse
- human needs are diverse.

A paradigm shift is required!

Increased production is the answer?

- the pressure on basic inputs is intensifying
- food security also requires risk management
- product quality and cultural diversity are linked.

A challenge: production + productivity gain.

Genetics is only for the future?

- genetics + environment = low cost, sustainable production + high productivity
- capacity is required to respond to economic, social, environment change.

Biological systems are moderated by their genetic composition.

Ninety per cent of the breeding is the feeding?

- large, between-animal differences remain at all input levels
- genetic change is compounding: over offspring, grand-offspring, etc.

The answer is generally: feed + health + genetics + husbandry.

Biotechnologies are relevant to developed countries only?

Developing world animal issues	Biotech applications
Disease surveillance/control	Immunological, molecular
Simplified *ex situ* conservation	Reproductive, development
Comparative uniqueness of breeds	Molecular
Genetic development efficacy	Reproductive, molecular
Farm energy production and nutrient recycling	Molecular
Product processing/quality surveillance	Molecular

Challenges: relevance + adaptation of biotechnologies.

Animal genetic resources

What are farm animal genetic resources (AnGR)?

- the few animal species on which humans depend for much food and agriculture, plus the breeds of each species.

Why are AnGR important?

- provide the biological capital to sustain and develop food and agriculture.

How many AnGR?

- approximately 5000 remain.

Where are these AnGR?

- unique AnGR in most countries
- majority in developing countries.

What is the current state of AnGR?

- very few developed

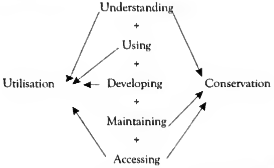
- negligible under development in developing countries
- almost 1/3 at high risk of loss
- negligible conservation activity.

Why so many at high risk?

- Indiscriminate import/use of exotics.

  An issue: Rate of loss versus replenishment.

What is 'AnGR Management'?



Successful management is technically and operationally challenging.

Countries requested the Food and Agriculture Organization of the United Nations (FAO) to develop a strategic framework for use in managing AnGR.

Developing the strategic framework for the management of farm animal genetic resources

In the early 1990's the governing bodies of the Food and Agriculture Organization of the United Nations (FAO) considered the state of animal genetic resources (AnGR) and asked FAO to examine the feasibility of developing a 'global programme of management' for this sector of agro-biodiversity, with a view to upgrading the characterisation, use and development and maintenance of the resources involved. This action was followed closely by the United Nations Conference on Environment and Development (UNCED) in June 1992 and its outcomes such as the signing of Agenda 21 (with its monitoring Commission on Sustainable Development), the Agreement on Climate Change, the Desertification Convention and the Convention on Biological Diversity or CBD.

Development of a framework for a strategic approach to the management of AnGR was

- initiated by the FAO's Animal Production and Health Division over 1993 to 1995
- considered by the Organisation's Programme Committee over 1994–96 and supported for continued development
- reviewed in 1995 by the Committee on Agriculture (COAG) and supported for development over a 15-year period, the committee proposing that FAO was the appropriate organisation to assume the lead role in developing the strategy, with the organisation (FAO) being responsible for global co-ordination, facilitation and reporting
- supported by Council in 1995, which acknowledged that extra-budgetary resources would also be required to develop the strategy and assist countries with its implementation; and that involvement should be sought from the broad spectrum of stakeholders
- accepted by the FAO Conference in 1995 as a priority activity for introduction to the organisation's programme of work and budget beginning 1996–97.

The strategic framework for the management of AnGR includes a set of key actions that aim, in particular, at

- developing and making better use of AnGR, with emphasis on those adapted to the world's major medium-input and low-input production environments, thereby contributing to the sustainable intensification of these agricultural systems, and
- overcoming the serious threat of genetic erosion in the remaining 5000 or so breed resources of the 14 or so farm animal species of greatest importance to achieving food security; when preliminary survey results show that about 30% of these resources are currently at high risk of loss.

The strategic framework which is progressively being shaped and developed incorporates four fundamental components

1. an inter-governmental mechanism, whereby Member States of FAO can directly guide the technical development of the strategy and guide international policy development concerning AnGR: the Commission on Genetic Resources for Food and Agriculture and its Intergovernmental Technical Working Group on Animal Genetic Resources
2. a country-based planning and implementation infrastructure, containing three elements: (i) focal points and their networks, (ii) a donors and stakeholders involvement mechanism, and (iii) the Domestic Animal Diversity Information System (DAD-IS)
3. a technical activities programme, of six elements: (i) national management plans for AnGR, (ii) sustainable intensification, (iii) characterisation, (iv) conservation, (v) communication, and (vi) emergency plans and a response mechanism
4. a reporting and evaluation component, of four elements: (i) preparation of the Report on the State of the World's AnGR, (ii) country reports, (iii) country and global monitoring, and (iv) development of the early warning system for AnGR, incorporating the World Watch List for Domestic Animal Diversity.

The strategic framework also incorporates six capacity building and six technical assistance elements which cut across the four components (Table 1).

Table 1. *Constituents of the global strategy.*

Components	Inter-governmental mechanism	Country-based planning and implementation infrastructure	Technical programme of work	Reporting and evaluation
Elements	Commission on Genetic Resource for Food and Agriculture	Global focal point	National management plans for AnGR Sustainable intensification	First report state of the world's AnGR
	Inter-governmental technical working group on animal genetic resources	Regional focal points	Characterisation Conservation	Country Reports
	National governments	National focal points	Communication	Country and global monitoring
		Donor and stakeholders involvement mechanism DAD-IS	Emergency plans and response	World Watch List-Early warning system
Capacity building	Training and education Technology transfer	Guidelines Research	Data and information management Communications and co-ordination	
Technical assistance	FAO experts Expert meetings Research	Information panel of experts Advanced data and information software	Cadres of experts	

The strategy was strongly supported by the Conference of the Parties to the Convention on Biological Diversity which in its Decision III/11 also recognised FAO's lead position, and strongly supported the strategy's further development. A joint programme of work with the CBD Secretariat is being developed, complementary to and based on the planned work programme by the FAO Global Focus under the strategy.

The technical rationale on which the framework for the global strategy is based was evaluated and endorsed by the First Session of the Informal Panel of Experts on Development of the Global Strategy and further detailed at the Panel's Second Session in March 1998.

The development of the strategy was considered in September 1998 by a first session of a regionally balanced Intergovernmental Technical Working Group on AnGR, newly established by FAO's Commission on Genetic Resources for Food and Agriculture. The Working Group recommended, *inter alia*, FAO continuing to shape and develop the strategy and to involve all stakeholders.

The rationale for the strategy emphasises the central importance to realising sustainable intensification of food and agriculture production by basing genetic development activity

on adapted AnGR. This proposes a paradigm shift in the genetic development of animal populations for food and agriculture production. The strategy is also targeted at assisting countries to implement their commitments in the World Food Summit Plan of Action.

The strategic framework takes a comprehensive approach to managing AnGR, with particular emphasis on country focus and responsibility. It will increasingly emphasise use and development of AnGR but in the short term, and particularly because of the large fraction of global AnGR seemingly at high risk of loss, with very little recorded information about the majority of these resources, countries have resolved that conservation action must also be emphasised.

The constituents of the global strategy (Table 1) are interdependent and must be implemented concurrently to be cost-effective, maintain momentum and achieve long-term success. Once the basic guidelines and framework are in place, activities need to be developed in a coherent manner, as the necessary human and financial resources become available. For success, the broad spectrum of stakeholders must be involved, from countries and their local communities to international research, development and collaborative agencies.

The cost-effective management of AnGR is technically challenging, both in breadth and depth. Hence, the rapid development and field evaluation of technical guidelines which address each constituent of the framework is both a priority and a challenging activity for FAO in the role allocated to it by the governing bodies: to lead, co-ordinate and facilitate activities required to develop the strategy, and to report globally.

Another important tool being developed particularly for country use as an aid in the broad spectrum of AnGR management activity is the information and communication system, DAD-IS. The structure user group emphasising the National Co-ordinators for AnGR and their networks is beginning to take up the system now it is available on and off line and in several languages, but much remains to be done. Again, FAO seeks stakeholder involvement in this system's development.

Countries are beginning to become involved with implementing the strategy. Many opportunities exist for developing both the resource base — human, technical and financial — and operational modalities.

Revealed preference valuation methods for farm animal genetic material: Principles, strengths and weaknesses

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Economic value

It is best to start by reminding ourselves what economists define as 'value.' Economic value is commonly expressed in monetary terms, but it is in fact interpreted by economists as a difference in utility levels. Economic value measures the change in the level of satisfaction of an individual. Under some assumptions these individual measures can be aggregated to provide collective measures of welfare change.

Valuation methods based on *revealed preferences* are based on the availability of *observable* transactions for the commodities of interest in properly functioning markets. By exchanging money for commodities agents 'reveal their preferences.' As such all flows of services and consumption provided by animal genetic resources (AnGRs) which escape market transactions cannot be valued by revealed preference methods.

From these transactions economists can estimate the essential stylised traits of market behaviour, starting with the market supply function for a particular animal product and its market demand function.

The market demand function $D_i(p_i, p_{-i}, m)$ measures the quantity demanded in a market when the prevailing price for the commodity is p_i, the price of substitutes for the commodity is p_{-i} and the total budget of the community for that category of expenditures is m.

The market supply function $S_i(w, p_i)$ measures the quantity supplied in a market when the prevailing price for the commodity is p_i, and the vector of input prices for the input required for production is w.

The market equilibrium price p^* is the price at which there is no excess demand, that is, the price at which the market clears and

$$D_i(p_i, p_{-i}, m) = S_i(w, p_i).$$

Given a prevailing market price, all doses of the animal commodity are accessible at that amount. But, as demand slopes downward, buyers (consumers) in the market may be willing to pay higher amounts for doses of product smaller than the equilibrium quantity. So an adequate measure of economic value for buyers (consumers) is the consumer's surplus

associated with a given prevailing price. At each amount this is the difference between the market willingness to pay for a given amount and the prevailing price. In its entirety this is the area between the market demand schedule and the line of the prevailing market price.

Similarly, given a prevailing market price, with negatively inclined production cost functions (increasing marginal cost of supply), for some doses, market suppliers may be willing to accept prices lower than the prevailing one. So, an adequate measure of value for the supplier is the so called producer's surplus. This is the difference between the minimum price suppliers (producers) would be willing to accept for each dose of animal commodity and the prevailing market price.

Society is made of individuals who are in turn both suppliers and buyers, so an adequate measure of value for society as a whole is the aggregation of both surpluses.

How can one value the genetic resources of farm animals (farm AnGRs) in this revealed preference framework? AnGRs, along with animal nutrition and their environment, determine phenotypic traits. Improvement of economically valuable phenotypic traits allow three kinds of favourable market action

1. raise efficiency of transformation of inputs into outputs (demand effects)

This lowers marginal cost per unit of output hence it shifts the supply schedule to the right. Since now it is cheaper to produce, more product will be offered at any given price affecting both equilibrium price (in case this is the prevailing price) and extending aggregate surplus.

2. improve output quality (supply effects)

This increases maximum willingness to pay (WTP) at each dose hence it shifts market demand to the right, again affecting the market equilibrium price and extending aggregate market surplus.

3. create new animal products (research and development).

This provides potential for new markets and with them new surpluses.

Notice that some form of surplus is created in all markets in the treadmills between producers and final consumers. As a consequence, final animal products with high value added (e.g. Parma ham) can support more articulated markets and eventually produce higher aggregate market surpluses.

With properly functioning markets, a given breed of farm animals will be valued on the basis of how it contributes to the size of the surpluses in the markets that its output generates.

An important distinction to be made is between the economic value of the genetic resources of an individual animal, for which animal breeders have developed well established and sophisticated assessment techniques, and the economic value of pooled genetic resources. We are here interested in the latter, even though there is probably much to be learnt from the former.

The single breed can be a starting point for a conceptual framework that can then be extended to other genetic units. Within a given animal species a breed is a subpopulation with a specific and stable collection of phenotypical traits.

Methodology 1: Econometric demand and supply estimation

What question does it answer?

As mentioned above the estimation of these functions is an essential step in determining how the change in consumer's and producer's surplus reacts to changes in the vector of phenotypic traits.

How is it to be done?

This requires the estimation of conditional demand and supply functions. That is, of the amount demanded and supplied in the market at a given price, conditional on the values of the economically relevant phenotypic traits for which the connection with AnGRs is known.

Changes in the expression of these traits will produce shifts in the estimated functions, which in turn will bring about a change in consumer's and producer's surplus. From these shifts we can derive a measure of value for the individual traits and hence the underlying AnGR that are responsible for expressing these traits.

One can also estimate multiple demand equation (one for each breed), hence modeling explicitly the substitution effects across breeds, which may not be captured in conventional demand function analyses.

What data are needed?

The kind of data needed are

- market prices of individual market transactions involving consumer's and input commodities from farm animals
- level of expression of relevant phenotypic traits of the animal
- knowledge of the links between phenotypic traits and AnGR.

Strengths

- This method provides a good approximation to a theoretically sound measure of utility change for society.
- Multiple demand equation (one for each breed) is technically strongest and captures substitution effects well.

Weaknesses

- It requires good quality data on each transaction and information on how to map relevant phenotypic traits into AnGR.
- Multiple demand equation is data demanding and may be difficult to estimate.

- Econometric estimation of supply requires farm level data which are sometimes hard to get.
- There are special problems such as home labour and forage which may be hard to price or even measure.

Methodology 2: Hedonic valuation of animal characteristics

What question does it answer?

This valuation method is based on the principle that individual animals can be seen as a bundle of phenotypic traits which are relevant in terms of its economic performance. However, the bundle may also refer directly to the traits of the genetic endowment of the individual animal, as known on the basis of progeny analysis. Each of these traits contributes to the total economic value of the genetic resources of the individual animal. The collection of these values in the breed can be an indication of the genetic value of the breed itself.

The market value of the individual animal or breed will therefore be a function of these traits. This allows the identification of the marginal value of each trait, that is, the market price for that trait.

Under the assumption that a mapping can be identified between phenotypical traits and genetic material this method may be used to value the genetic resources responsible for particular traits and their intensity of expression in the phenotype.

How is it to be done?

Under competitive market conditions and with enough variability in the relevant vector of phenotypic (or genetic) traits of the animals transacted in the market, one can estimate a hedonic function which attempts to decompose the total value of the single animal transacted into its relevant traits and their intensity of expression.

What data are needed?

- records on levels of genetic endowment or expressions of different traits in the animal transactions
- market price of the animal transaction
- mapping between level of expression of phenotypic traits and some AnGR unit
- competitive market behaviour.

Strengths

- It can produce precise estimates of market prices for single traits and of specific AnGRs.
- Hedonic values are easy to estimate for current prices of characteristics.

Weaknesses

- The disadvantage is that it requires transactions in competitive markets and a large volume of good quality data on these transactions.
- It is difficult to estimate demand for characteristics and to relate these back to breeds except as raw estimate of premiums.
- It can be hard to do if relevant characteristics are unknown.

Methodology 3: Market share analysis of breed

What question does it answer?

It provides information on the total share of market value that can be attributed to a given breed. With well functioning and differentiated markets for the breed's product this should reflect the value to society of the bundle of traits embedded in the breed.

How is it to be done?

A simple market analysis of the total value of the products provided by a given breed.

What data are needed?

Market values of all products provided by category of animals broken down by breeds.

Strengths

It is easy to employ because it relies on relatively simple data and interpretation of results is quite straightforward.

Weaknesses

It relies on well functioning markets which may not be available and it could fail to measure consumer surplus.

Methodology 4: Farm-level simulations model of animal production

What question does it answer?

It models directly the effects of improved animal characteristics on the economics of farms.

How is it to be done?

In order to do this one must develop a farm model, using the farm as a multi-output production unit which employs a set of inputs. AnGRs are part of the input set and determine part of the technology available in this transformation.

In these models existing AnGRs determine farm animal phenotypic traits, which in turn affect the farm animal performance in terms of production. Functional traits can be empirically measured by formally including in the maximisation process as a set of constraints. Their shadow values may then be interpreted as marginal values of the effect of genetic improvements of these traits. The shadow value can approximately be thought of as the increase in the output function achieved by marginally relaxing a constraint.

What data are needed?

The data needed include stylised technical relationship between input and outputs in all the main farm activities, such as coefficients of technical transformation and of input substitution across farm production activities.

Strengths

The main advantage of this method is that it provides a more comprehensive definition of value of farm animal improvements as it accounts for substitution effects between inputs in the farm production process.

It is probably more useful in those agricultural contexts in which farm animals are only one of the various outputs of farms. It can incorporate mechanisms linking cause and effect and explore the effect of breeds not yet known.

Weaknesses

The main problem in this context is the correct definition of the objective function of the farm. This will mainly depend on the type of farm one seeks to model. Family farms are often modeled by posing as an objective function the family's utility function, which is then formalised over a set of factors, such as, for example, farm revenues, spare time, and long-term viability.

Industrial farms, on the other hand, are more frequently modeled under the conventional profit-maximising framework.

Another main disadvantage probably is that it requires the formulation of realistic objective functions for various typologies of farm management and a good knowledge of how the various productive processes come together in the overall farm activity.

Simulation approach can be backed by experimental methods and may show problems involving variables unknown to the analyst. Another weakness is that it does not often capture farm adaptation well.

Methodology 5: Deterministic and stochastic R&D model for AnGRs (genetic production function)

What question does it answer?

It provides information on how to most efficiently produce an animal with a new combination of relevant phenotypic traits using as inputs existing AnGRs.

Existing AnGRs can be valued on this basis by weighting the expected value of the new breed by the probability of this being successfully developed.

The expected value will reflect the discounted stream of benefits of the new breed over the period in which these benefits are expected to take place.

Deterministic models do not incorporate uncertainty of outcomes in research while stochastic models (search models) try to do this.

How is it to be done?

Most of the background technical (biological) information required to apply these models require that the economists involved work very closely with animal geneticists/breeders. This is probably more so for this than for the other methodologies.

What data are needed?

- prediction on market performance of the new breed
- prediction on the period over which benefits will occur
- information on the probability of success
- information on which existing AnGRs are valuable towards this task.

Strengths

- It allows to value existing AnGRs on the basis of potential future use.
- Basic deterministic models often provide clear messages.

Weaknesses

- requires little investigated probabilistic models for prediction of value
- search models sometimes are very complicated and behaviour of model hard to explain
- results may be subject to arbitrary choices of probability distribution and behaviour towards uncertainty
- deterministic models sometimes do poorly in modeling uncertainty
- require strong input from geneticists/breeding experts.

Genetic resource valuation methodologies, their strengths and weaknesses in application: The contingent valuation method

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Introduction

The use of animal genetic resources (AnGR) is characterised by: a) a high degree of 'non-rivalry', and b) a great deal of externalities stemming out from it. Both features call for public body intervention as a regulatory authority in order to ensure the optimal level of provision of such goods[1] and methodologies that allow for an appropriate resource allocation.

Here is where the need for non-market valuation come into the picture, i.e. for the valuation of goods or services that are not traded on a market and which do not have a market price which reveals consumer surplus (or which have a market price which does not fully reflect the utility society assigns to such goods or services).

According to the Total Economic Value (TEV) paradigm several components of value can be singled out (Table 1).

As stressed by Robert Mendelsohn (personal communication), empirical techniques for estimating resource values can be divided into two broad categories (Mitchell and Carson 1989): whether the method relies on revealed preferences in observed or on stated preferences in hypothetical markets.

The observed or market-based techniques (hedonic price, travel cost, random utility/discrete choice models, averting cost (behaviour) models) rely on the influence of the availability or quality of the resource on individuals' purchases of market goods, while hypothetical techniques (contingent valuation, contingent behaviour/choices) involve asking individuals to reveal values through responses to contingent questions or behaviour in contingent choice situations. I will talk about the contingent valuation method (CVM).

1. Of course, there could be other motivations for government intervention which do not derive from efficiency consideration, e.g. the ones that derive from equity consideration.

The contingent valuation method: Pros and cons

What is the contingent valuation method (CVM)?

CVM is a method for valuing goods that uses survey questions to elicit willingness to pay (WTP) for provision of the good (or WTA – willingness to accept compensation – for lack of provision/removal of the good), by developing a hypothetical market in which the respondents (to the survey) are given the opportunity to buy the good(s) in question. Because the elicited WTP values are contingent upon the particular hypothetical market, this approach is called CVM.

What do we include in the survey?

- a detailed description of the good to be valued and the hypothetical circumstance under which it will be made available to the respondent (make it as plausible as possible: what is the current status; what level of improvements; available substitutes, and the method of payment (higher taxes; higher water bills; higher food prices etc))
- questions to elicit WTP designed to obtain WTP without biasing respondent's WTP
- questions to obtain respondent's characteristics (age, income, education, etc), preferences for the good(s) being valued, use of good, and other information that may explain a person's WTP (or WTA) for the good(s).[2]

Table 1. *Taxonomy of total economic value component.*

Randall and Stoll (1983)	Fisher and Racucher (1984)		Boyle and Bishop (1987)	Freeman (1993)	Synopsis		
					Definition	Characteristics	
	Current use benefits	Direct use	Use values	Use values	Direct use values Consumptive UV Non-consumptive UV	*Ex post*	On-site, weak complementarity On-site weak complementarity
Use values		Indirect use			Indirect use values Vicarious consumption		Off-site, weak complementarity
			Non-use values		Option value		Static, risk aversion, soft uncertainty
	Intrinsic benefits	Potential use		Non-use values	Quasi-option value	*Ex ante*	Dynamic, preference for flexibility, hard uncertainty, learning by doing
					Bequest value	Inter-generational altruism	
Existence values		No use			Intrinsic value	Interpersonal altruism, benevolence toward people, sympathy toward animals, environmental responsibility	

2. This information could be used in regression equation to estimate a value function for the good. If we have a representative sample and the CVM is well designed, we can generalise results to the population with known margins of error (benefit transfer). Otherwise, this information could be useful in dealing with 'non response bias' (see 'Weaknesses').

Strengths and weaknesses of CVM

Strengths

1. directly obtains welfare measures
2. allows measurement of value of goods where other non-market valuation methods are not valid, i.e. measurement of non-use values (Table 2)
3. allows researchers to directly control the definition of the commodity.

Table 2. *A comparison of non-market valuation techniques.*

Desirable property	Method	
	Revealed (Indirect)	Stated* (Direct)
Able to obtain option price estimates in the presence of uncertainty	No	Yes
Able to value goods not previously available	No	Yes
Able to estimate all existence class benefits	No	Yes
Relevant ordinary (or inverse demand) curve is directly estimable	Yes	Yes
Relevant Hicksian compensated demand (or inverse demand) curve is directly estimable	No	Yes

* In some cases, only referenda have the desired property.
Source: Mitchell and Carson (1989: 88, modified).

Weaknesses

1. Can be very costly: e.g. the Exxon-Valdes CVM survey is estimated to have cost US$ 3 million![3]
2. Hypothetical answers can lead to over-or-understatements of true values (validity) (Table 2).

CVM issues

WTP vs WTA: Question of property rights

In practice, respondents have reported widely differing values for WTP and WTA. These differences depend on both income and substitution effects. The larger the income effects, the greater the divergence between WTA and WTP. Also, the less substitutable money (representing other goods) is for the non-market good, the greater the divergence between

3. This type of cost is usually incurred due to the use of large, statistically valid samples for CVM analysis. However, recent research has suggested that smaller convenience samples do a pretty good job in obtaining WTP estimates similar to larger, more statistically robust samples. Statistical validity may be important in legal applications of CVM (assessment of damages), but for policy and cost-benefit analysis, convenience samples may provide a more cost effective tool.

WTA and WTP. Most studies use WTP because it seems to provide a more conservative estimate of total value.

Problems with WTP

1. assumes full information about the public good, which may not be available
2. valuations based on WTP are also based on ability to pay: thus, for local environmental externalities in income-poor areas, desire to improve environmental quality may not be reflected by WTP.

When do you use WTA vs WTP?

Depends on the assignment of property rights. If property rights are assigned to the consumer, then WTA is the theoretically correct measure. If property rights are assigned to the government (or to the polluting firm for an environmental quality good), the WTP is the correct measure.

In short, does the respondent have the right to sell the good or, if he wants to enjoy it, does he have to buy it? Because property rights in public goods are held collectively, this question is often not an easy one (also perceived property rights - at least in CVM - may be more important than actual legal ones).

Hypothetical questions, hypothetical answers, and getting at the 'truth' with CVM

Hypothetical bias: Difference between what people say and do. Problem arises from lack of incentive to reveal one's real preferences. To minimise this problem, the researcher must create a believable and meaningful set of questions and should make the scenario as plausible as possible.

Respondents should believe that their actions will be considered in the decision-making process.

Be sure to give subjects a chance to respond 'do not know' to questions seeking their opinion.

Strategic bias

- Free-riding: Respondents underbid because they think that a) they will have to pay the amount they indicate, and b) the good will be provided no matter what amount they indicate
- Over-pledging: Respondents overbid because they think that a) they will not have to pay the amount they indicate, and b) provision of the good depends on their indicated WTP.

Strategic bias can be limited by using incentive compatible question formats, such as dichotomous choice or iterative bidding.

Instrument bias: Question ordering and wording. Context can influence answers to questions: Have to be careful not to provide value cues or indicate the surveyor's assertions.

Reliability: Refers to the extent to which the variance of an estimate, such as mean WTP, is due to random sources or 'noise.' Reliability is usually a function of survey design elements, such as sample size (Mitchell and Carson 1989).

Validity: Measures the extent to which an instrument measures the concept under investigation. From a statistical standpoint, validity is the absence of systematic error or the extent to which a measure is unbiased (Mitchell and Carson 1989).

- Content validity: Refers to whether the design and execution of the study were conducive to the revelation of theoretical WTP or WTA.
- Construct validity: Deals with the degree to which the measure under scrutiny (in our case CVM estimates of WTP or WTA) relates to other measures as predicted by theory and intuition.
  - Convergent validity tests consider the relationship between the CVM measure of the good's value and alternative measures of the same value.
  - Theoretical validity tests consider the relationship between the CVM measure and independent variables that are thought, based on theory and intuition, to be potential determinants of WTP or WTA.
- Criterion validity: Mitchell and Carson (1989) point out that 'it is necessary to have in hand a criterion which is unequivocally closer to the theoretical construct (mean WTP or WTA) than the measure whose validity is being assessed (the CVM-based measure of value)'.

Validity is likely to be a serious concern for individual CVM studies. Current work has shown relatively good correspondence between hypothetical CVM markets and simulated markets (see below).

Familiarity with non-market goods (Cummings et al 1986): Individuals go through a process of 'crystallising' their values for particular goods. Unfamiliarity with valuing non-market goods can lead to wide variations in reported WTP from one time to another for the same individual.

Budget constraints and liquidity.

The Exxon–Valdes, the NOOA panel, and recommendations for CVM (USDC–NOOA)

1. Respondents should value larger changes more than smaller changes and additions to WTP should decline as the level of environmental quantity/quality increases (decreasing marginal utility).
2. Respondents should take their budget constraints seriously.
3. Respondents should seriously consider the availability of private and public substitutes for the commodity.

Main conclusion

CVM studies can provide useful information about economic values for policy analysis and litigation, provided that the studies individually demonstrate a high degree of validity.

Survey design

Commodity definition

What is the issue being studied and how does it relate to people? The commodity defined must be theoretically accurate, i.e. represent the issue you are studying, understandable to people, and believable.

1. Substantive definition
    - Attributes
    - Context: Is the resource unique? Are there restrictions on use of the resource? Does the resource have multiple values, i.e. historical significance, scenic beauty, habitat?
    - Source of change in the good: Predominantly natural (forest fires, dust storms, etc) or predominantly human (pollution, effluents, oil spills, etc).
2. Formal definition
    - Reference and target levels: What is the magnitude and direction of change in the good?
    - Extent of change: What area does the change cover? How long will the change take? How long will it last?
    - Timing of change: When will the change take place?
    - Certainty of provision: Is the change guaranteed? For example, some policies to improve environmental quality do so by reducing the risk of pollution events. In these cases, the environmental quality good is not guaranteed to be available, only the probability of provision is changed. This can affect whether respondents provide a true WTP for the good or whether they are providing an option value.

Defining value measures: Money, time, risk

a) Substantive definition
- Attributes
- Context: Utility bill, income tax, entry fees, environmental fund donation (note that all of these excepting direct taxes or direct contributions to a fund will have impacts on the quantity of the good or related goods)
- Constituency: Who will have to pay? For example, in a tax scenario, the cost burden will be shared by all taxpayers, while for an entry fee, only those who use the resource will have to pay.

b) Formal definition: Payment form
- Extent: How often will they have to pay, and for how long?
- Timing: When will they have to pay?

- Certainty: Will they have to pay up front, or only if something occurs (for example, if there is a drought, water prices may go up).

Instrument bias

Question ordering, wording, and use of informational aids. When providing information, it must be value neutral.

Allowing for

- internal consistency checks
- 'do not know' in CVM responses
- protest bids
- pre-tests and focus groups.

Question format

1. Direct/open ended: Easiest question format. 'How much are you WTP in extra taxes for X? US$ — per year.'
    - Phrasing is important in open-ended questions and may give value-cues to the respondent.
    - Idea of property rights is also involved here. You will get different results if people are asked how much they are WTP or WTA
    - for some goods it may be difficult for respondents to pick a value out of the air. Unfamiliarity with the goods or services may lead to high number of non-respondents.
2. Iterative bidding (Figure 1): modeled on the auction approach. Here interviewer asks respondent if he/she would be WTP US$ X per year (or whatever). Depending on the answer, the interviewer will then increase (if yes) or decrease (if no) the bid until the maximum WTP is obtained. It is a series of dichotomous choice questions.

- Advantages
    - familiar to people (auction)
    - simple nature of choice (yes or no)
    - bidding process is likely to capture maximum WTP
    - requires smaller sample.
- Disadvantages
    - Starting point bias: Researchers found that starting bids well above true WTP, tend to increase revealed WTP, while starting bids well below true WTP tend to decrease revealed WTP.
    - In some elicitation questions, the starting bid may affect the maximum WTP. The effect depends on how the respondent perceives the starting bid, e.g.

- starting bid is in likely range of expected payment - responds quickly to please interviewer
- starting bid far away - respondent gets tired of bidding and respond randomly.

3. Payment card (Mitchell and Carson 1981)

Lists a series of values from which respondents choose an amount that best represents their maximum WTP.

Another payment card type is where the card indicates per capita spending for various public services for people in respondents income bracket. Then respondents are asked to state value-invites in comparisons with other products.

The checklist method is a special case of the payment-card. Here the respondent is given with a list of values and asked to circle the highest he/she would be WTP.

- Advantages
  - use of payment cards may facilitate respondent's valuation process.
- Disadvantages
  - can be subject to biases associated with ranges used on the card (known as range bias).
  - some respondents will choose first or last in a sequence.

4. Closed ended (=discrete/dichotomous choice) single-bounded (Bishop and Heberlein 1979; Hanemann 1984; Hanemann and Kanninen 1998)

Yes-no choice is commonly refered to as dose-response modeling in biometrics.

In general, this is the most recommended form for CVM questions. It replicates the market form most respondents are familiar with, i.e. a good is priced for sale and a consumer decides whether to buy the product at the listed price. Similar to consumer surplus idea.

One may use either *logit* or *probit* function to get WTP (Figure 1).

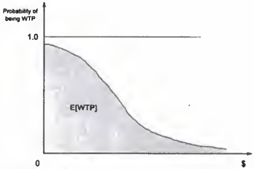

Figure 1. *Probability of being WTP.*

$$\Pr\{\text{response is 'yes'}\} = 1 - G_c(A) = 1 - G\left(\frac{A-\mu}{\sigma}\right),$$

where A is the bid, C the respondent max WTP and $G_C(\cdot)$ could be either the standard normal cdf, $\Phi(x)$, or the standard logistic cdf, $1/(1+e^{-x})$.

Here you ask the person whether he/she would be willing to pay US$ X per year (or whatever period) in extra taxes (or bill or any payment vehicle) for the good in question? Yes or no.

The US$ X amount is varied among subjects. That is, you divide your sample into groups and you assign each group a different value of US$X. The response to this type of question is 'yes' or 'no'. Yes if his/her true WTP>US$ X and not otherwise. An example is presented in Table 3.

Table 3. *Example of closed-ended WTP.*

US$ X (bid)	Number of assignees	Number said Yes	Pr (yes)
1.00	50	40	0.8
5.00	40	20	0.5
10.00	20	8	0.4
15.00	10	3	0.3
25.00	5	1	0.2

Advantage

Closed-ended question is like the type of market we actually use for most of our purchases (there is a given price which we take or leave[4]).

Why does dichotomous choice reduce strategic bias?

- more closely approximates market conditions
- less incentive to lie – If true WTP is greater than offered amount, it is to the respondents benefit to respond with a 'yes.' If true WTP is below the amount then they may say 'yes' if they are attempting to over pledge, but the amount of bias is reduced relative to an open-ended question.

Disadvantages

- it requires larger samples
- may need to make assumptions on statistical distribution of WTP to estimate the WTP function (the statistical model must be consistent with economic theory: random utility model, RUM).

However, recently non-parametric and semi-parametric techniques have been developed to estimate WTP from discrete data (increased flexibility).

- Non-parametric: no parametric estimation of WTP distribution (examples: 'pool adjacent violators algorithm' (Ayer et al 1955; Kriström 1990); distribution smoothing using kernel functions (Copas 1983; Staniswalis and Cooper 1988)

4. Consequently this approach is also called 'take-or-leave-it approach,' or 'dichotomous-choice,' or 'referendum' approach.

- Semi-parametric: either the error distribution or the indirect utility function – but not both, are non parametric (examples: Cosslett's (1983) extension of PAVA, Li (1996); Manski's (1975) maximum score estimator; Horowitz's (1993) smoothed MSE).

Choice of welfare measure (Hanemann 1984; Hanemann and Kanninen 1998)

- Mean vs median (or other quantile of the WTP distribution)
  - mean is the conventional measure in benefit-cost analysis and reflects the Kaldor-Hicks potential compensation criterion
  - median may be more realistic in a world where decisions are based on voting and there is concern for the distribution of benefits and costs.

From a statistical point of view, the mean is generally far more sensitive than the median to the choice of a response probability model or the method of estimation.

- Parametric vs non-parametric welfare measures
  - the estimates of median WTP obtained using non-parametric or semi-parametric estimation do not differ greatly from those obtained with a parametric approach
  - the estimates of mean WTP can differ considerably
  - note that, since there is no parametric specification of the underlying RUM model, it is not possible to extrapolate from the observed contingent value (CV) responses to measure other items not directly covered in the survey.

Focus groups/pre-testing should be used to develop the ranges for closed end questions (see 'optimal design' below).

5. Closed ended double-bounded (Carson 1985; Hanemann 1985) (Figure 2)

These formats can be used to improve the validity of the results. You get additional information by asking the respondent two dichotomous choice questions. The first establishes an initial point, either below or above the theoretical maximum WTP. The second question is asked contingent on the response to the first—if the respondent answers no to the first amount, a lower bid is offered, otherwise, a higher bid is offered.

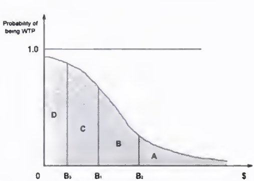

Figure 2. *Double bounded dichotomous choice format.*

In the former case, if the respondent answers yes, then true WTP is known to be between the initial bid and the follow-up bid. If the respondent answers no, then true WTP is known to be below the follow-up bid. In the latter case, the reverse holds. If the respondent answers no to the follow-up bid, then the true WTP is between the initial bid and the follow-up bid, otherwise, the true WTP is somewhere above the follow-up bid. This additional information can improve the quality of consumer surplus estimates. An example is presented in Table 4.

Table 4. *Example of closed-ended double bounded design.*

Answers	Conclusions	Region
Yes/Yes	$WTP>B_2$	A
Yes/No	$B1<WTP<B2$	B
No/Yes	$B3<WTP<B1$	C
No/No	$0<WTP<B3$	D

Experimental design

1. Questionnaire design
2. Survey method
    - in person interviews
    - telephone interviews
    - mail surveys.
3. Sampling plan: The goal of optimal experimental design is to find the bid values that provide the maximum possible information about the parameters of the WTP distribution, given the size of the sample (Duffield and Patterson 1991; Alberini and Carson 1993; Cooper 1993; Kanninen 1993b; Alberini 1995).

C-optimal (minimum variance or some related statistics of the parameter estimates) versus D-optimal (minimum variance of welfare measure constructed from them).

Mainly *logit* model is applied in analyses because of its simplicity.

Findings

- Bid points from the tails of a distribution are generally uninformative: for the logistic distribution, we observed that this ruled out bid points in the outer 12% tails of the distribution
- Conduct the CV survey sequentially: this approach gives the researcher flexibility for updating the bid designs so that the final bid design, given several iterations, can be close to optimal (Table 5)
- by doing this, one might end up with, say, four to six bid points: as a matter of general practice, one should avoid having many more bid points than this.

Table 5. *Performance of simulated sequential single bounded c-optimal logit cv design.* [a,b]

Number of survey iterations	Number of observations per iteration	Mean squared error of WTP relative to c-optimal design
1	500	101.42
2	250	2.46
3	166	1.34
4	125	1.32
5	100	1.23

a. These simulations are based on a logistic distribution with parameters a=2.5, b= – 0.01; expected median WTP = 250, n=500.

b. Taken from Kanninen (1993a).

c. Based on the specified parameters and sample size, a C-optimal design would produce a mean squared error estimate of $4/n\beta^2$ for the single-bounded model (Kanninen 1993b).

Analysing the results

1. Extreme responses may reflect a misunderstanding of the question or a lack of consideration of opportunity costs and budget constraints.
2. Zero responses
   - Some may be true reflections of zero worth or income constraints
   - Others may be protest responses (unit vs item non-response bias)
     - Some respondents may reject the whole idea of placing values on the commodity.
     - Some respondents may reject the form of payment (e.g. they do not like taxes).
     - Some respondents may reject the property rights arrangements, e.g. 'Why should one pay to clean up pollution caused by someone else?'

Conclusions

What makes a good CVM study is the practical interplay between economics, statistics, and survey research.

Individual CVM study validity

Psychologists (Bohrnstedt 1983) have applied three strategies to assess the accuracy of their methods (the '3Cs' approach): these are content validity, construct validity, and criterion validity. Environmental economists have already begun to adapt the 3Cs to contingent valuation (Mitchell and Carson 1989; Champ 1994; Bishop et al 1995, 1997).

Overall CVM study validity

Carson et al (1996) performed a rigorous analysis across CVM studies and found 83 which supported 616 comparisons with revealed preference studies. All the studies involved WTP.

For the full set of comparisons, the ratios of contingent values to revealed-preference values averaged 0.89 with a 95% confidence interval of [0.81–0.96] and a median of 0.75. The Spearman rank correlation coefficient for contingent values and associated revealed-preference values was 0.78 .

These results would support the conclusion that CVM studies are tending to produce value estimates that are rather close to those from revealed-preference studies in cases where both are possible. These are rather encouraging results, although more evidence regarding non-use values, where revealed-preference methods do not work well, would be helpful.

CVM and AnGR valuation

Some background remarks on AnGR values

As mentioned by Robert Mendelsohn (personal communication), AnGR provides several sources of value which fit with the total economic value (TEV) components classification (Table 1).

1. Use of AnGR for the production of higher quality goods and/or for improving agriculture productivity are examples of consumptive use values.
2. Sometimes, even not so common, outdoor recreation can be motivated by the presence of rare (traditional and/or endangered) animal species and landraces: this is clearly a non-consumptive use value.
3. Moreover, people could also derive satisfaction from reading publications, viewing pictures, watching TV programmes on given animal species: this is called a vicarious use value.
4. The use of AnGR as an input for future products calls for what have been defined option and quasi-option values.
5. The mere existence of given animal species can motivate existence value, even if they have no market value.

All these value components are important, since such a classification leads in turn directly into the classification of empirical techniques for measuring resource values.

First of all, it should be said that in valuing AnGR we are mainly interested in using it as genetic material for production, that is non-consumptive (recreation) as well as vicarious use (cultural interest) are not so important in that context. However, the available techniques for the empirical estimates of such value components could be both revealed (e.g. travel cost, hedonic pricing, etc) and stated (i.e. contingent valuation) approaches.

As pointed out by Mendelsohn (1999), and further developed by Scarpa (1999), use values can be evaluated, again, using both revealed and stated preferences approaches, since

there is a linkage between public or semi-public goods and the private goods market candidates (weak complementarity or substitutability between AnGR and private goods). The observed market behaviour techniques (both using 'indirect' data on agricultural total factor productivity, see Evenson et al 1998, and 'direct' experimental data on genetic contribution to improved performances of a given species, see Mitchell et al 1982) should be preferred, leaving the use of hypothetical methods as corroboration of the estimate invoking convergent validity.

The existence value — since it is a pure non-use value — can be justified on the basis of altruistic motivations: having no relations with private good market (no weak complementarity/substitution condition), the only approach that could be used is contingent valuation.

Option and quasi-option values deserve a few more comments, since they capture the very essence of agricultural genetic resource issues: insurance and information (Swanson 1996, 1998). Insurance refers to the value of genetic diversity in providing a broad base of independent assets on which to build production. Information refers to the uncertainty that exists about the future, and what will be revealed with the passage of time.

The option value component is a 'portfolio value', derived from the retention of a relatively wider range of assets within the agricultural production system. As suggested by Evenson et al (1998) analysing actual farmers behaviour will give us some information to derive an estimate of such a value, via market techniques. However, since other effective tools for hedging against risk are becoming more and more widespread, this approach seems to be flawed.

The quasi-option value could be thought as made-up of different components: the value of future information and the value of exploration.

The first one is the value of retaining a wider portfolio of assets across time, given that the environment is constantly changing and rendering known characteristics far more valuable than they are currently considered. The evaluation of this value is far from being fully exploited: in principle, stated preferences techniques could be used, but ignorance of the future and the complexity of scenario design (see below) undermines both the reliability and the validity of such studies. Nevertheless, the information value is important, because it represents the rationale for *in situ* conservation strategy, based on the application of the precautionary principle and minmax strategies (Bishop 1978, 1993).

The second one is the value of retaining a wider portfolio of assets across time, given that the exploration and use of little-known assets will generate discoveries of currently unknown traits and characteristics (Pindyck 1991). This is a 'bayesian' sort of value, where information derives from the process of converging expectations. This value is the basis for *ex situ* conservation strategy. Here, both revealed (Evenson et al 1998, 'mapping genetic flows' approach) and stated preferences could be used, though the latter case poses serious problems of strategic bias (see below).

CVM and AnGR valuation

I have stressed that the value of a CVM study rests on its reliability and validity. Only studies that pass the '3Cs' test mentioned above, can be considered valid. Now, while it could be in

principle conceivable to conduct a CVM study whose construct and criterion validity can be under scrutiny, it is hardly conceivable that an AnGR CVM study could pass the content validity test.

There are two issues which undermine the use of CVM for AnGR valuations (at least with reference to AnGR use-value components):

1. The unfamiliarity of respondents with the good to be estimated and the complexity of such a good (i.e. the impossibility of providing the respondent with an accurate, understandable and believable commodity definition), and
2. The constituency (i.e. the property rights assignments) about who will have to pay and how, for the good under examination.

As pointed out by Evenson (1993), CVM approaches seem to be 'ill-suited' to measuring the value of genetic resources, since an average individual knows little about germplasm collections, breeding techniques, etc. Only specialists are competent to understand the breeding processes, but restricting the sample only to specialist causes a bias in the estimation which is similar to the non-response bias in standard CVM studies, stemming from population segmentation.

Moreover, even in the case of a study that will take into account only specialists, the danger of strategic bias could be very high, if the researcher does not take explicitly into account a clear definition of the institutional framework within which the good has to be valued and/or the respondents feel that the institutional setting (i.e. the study implied property rights assignment) is not coherent with their own like-to-be property rights assignment or, even, the *status quo*. Since such an institutional setting is still under flux, the danger for strategic bias is high.

With reference to this point, however, AnGR valuation seems to have a comparative advantage as compared to plant genetic resources (PGR) valuation. Indeed, in AnGR breeding activities there is room for more control over reproduction and markets are more complete than PGR. Therefore, at least in principle, it could be possible to design institutions which will strengthen property rights on AnGR, which in turn could lead to more efficient markets[5] and, eventually, to an easier valuation of AnGR (via revealed as well as stated preferences approaches).

This is a crucial point, which must be addressed also for policy intervention. From the mere valuation point of view, it will help to clarify the very complex picture of AnGR field, but will not eliminate all the CVM problems, as applied to AnGR valuation. This is why revealed preference approaches seem to be better suited for this kind of valuation.

The field of applicability of CVM in AnGR valuations seems to be restricted to non-consumptive and vicarious use values, where it can play a corroborating role as convergent validity tool of revealed preference estimates (and vice versa), as well as to existence values, provided that the studies individually demonstrate a high degree of validity (i.e. they fulfil all conditions prescribed by the NOOA panel).

5. It remains to be seen, however, how perfect those market could be, due to markets power considerations.

References

Alberini A. 1995. Testing Willingness to Pay Models of Discrete Choice Contingent Valuation Survey Data. *Land Economics* 71 (1): 83–95.

Alberini A. and Carson R.T. 1993. Efficient Threshold Values for Binary Discrete Choice Contingent Valuation Surveys and Economic Experiments. Resources for the Future Discussion Paper, Quality of the Environment Division. Resources for the Future, Washington, D.C., USA.

Ayer M., Brunk B.D., Ewing G.M. and Silverman E. 1955. An Empirical Distribution Function for Sampling with Incomplete Information. *Annals of Mathematical Statistics* 26: 641–647.

Bishop R.C. 1978. Endangered Species and Uncertainty: The Economics of a Safe Minimum Standard. *American Journal of Agricultural Economics* 60 (1): 10–18.

Bishop R.C. 1993. Economic Efficiency, Sustainability, and Biodiversity. *Ambio* 22 (2–3): 69–73.

Bishop R.C. and Heberlein T.A. 1979. Measuring Values of Extramarket Goods: Are Indirect Measures Biased? *American Journal of Agricultural Economics* 61 (5): 926–30.

Bishop R.C., Champ P.A. and Mullarkey D.J. 1995. Contingent Valuation. In: Bromley D.W. (ed), *Handbook of Environmental Economics.* Basil Blackwell, Oxford, UK.

Bishop R.C., Champ P.A., Brown T.C. and McCollum D.W. 1997. Measuring Nonuse Values: Theory and Empirical Applications. In: Kopp R.J., Pommerehne W.W. and Schwarz N. (eds), *Determining the Value of Non-Marketed Goods: Economics, Psychology, and Policy Relevant Aspects of the Contingent Valuation Method.* Kluwer Academic Press, Dordrecht, The Netherlands.

Bohrnstedt G.W. 1983. Measurement. In: Rossi P.H., Wright J.D. and Anderson A.B. (eds), *Handbook of Survey Research.* Academic Press, New York, USA.

Carson R.T. 1985. Three Essays on Contingent Valuation (Welfare Economics, Non-Market Goods, Water Quality) PhD Dissertation. Department of Agricultural and Resource Economics. University of California, Berkeley, USA.

Carson R.T., Flores N.E., Martin K.M. and Wright J.L. 1996. Contingent Valuation and Revealed Preference. *Land Economics* 72 (1): 80–99.

Champ P.A. 1994. Nonmarket Valuation of Natural Resources Amenities: A Validity Test of the Contingent Valuation Method. PhD Dissertation. Department of Agricultural and Applied Economics. University of Wisconsin, Madison, USA.

Cooper J.C. 1993. Optimal Bid Selection for Dichotomous Choice Contingent Valuation Surveys. *Journal of Environmental Economics and Management* 24: 25–40.

Copas J.B. 1983. Plotting *p* against *x*. *Applied Statistics* 32 (1): 25–31.

Cosslett S.R. 1983. Distribution-Free Maximum Likelihood Estimator of the Binary Choice Model. *Econometrica* 51 (3): 765–82.

Cummings R.G., Brookshire D.S. and Schulze W.D. 1986. *Valuing Environmental Goods: An Assessment of the Contingent Valuation Method.* Rowman and Allanheld, Towota.

Duffield J.W. and Patterson D.A. 1991. Inference and Optimal Design for a Welfare Measure in Dichotomous Choice Contingent Valuation. *Land Economics* 67 (2): 225–39.

Evenson R.E. 1993. Genetic Resources: Assessing Economic Value. Department of Economics. Yale University, New Haven, USA. Unpublished Manuscript.

Evenson R.E., Gollin D. and Santaniello V. (eds). 1998. *Agricultural Values of Plant Genetic Resources.* CAB International, Wallingford, UK.

Hanemann W.M. 1984. Welfare Evaluation in Contingent Valuation Experiments with Discrete Responses. *American Journal of Agricultural Economics* 66 (3): 332–41.

Hanemann W.M. 1985. Some Issues in Continuous and Discrete Response Contingent Valuation Studies. *Northeastern Journal of Agricultural Economics* 14 (1): 5–13.

Hanemann W.M. and Kanninen B. 1998. The Statistical Analysis of Discrete-Response CV Data. Working Paper 798. Department of Agricultural and Resource Economics. University of California, Berkeley. In: Bateman I.J. and Willis K.G. (eds), *Valuing Environmental Preferences:*

Theory and Practice of the Contingent Valuation Method in the US, EC, and Developing Countries. Oxford University Press, Oxford, UK. (In press)

Horowitz J.L. 1993. Semiparametric and Nonparametric Estimation of Quantal Response Models. In: Maddala G.S., Rao C.R. and Vinod H.D. (eds), *Handbook of Statistics*, Vol. 11. Elsevier Science Publishers, New York, USA.

Kanninen B.J. 1993a. Design of Sequential Experiments for Contingent Valuation Studies. *Journal of Environmental Economics and Management* 25: S-1-11.

Kanninen B.J. 1993b. Optimal Experimental Design for Double-Bounded Dichotomous Choice Contingent Valuation. *Land Economics* 69 (2):138-46.

Kriström B. 1990. A Non-parametric Approach to the Estimation of Welfare Measures in Discrete Response Valuation Studies. *Land Economics* 66 (2):135-39.

Li C.Z. 1996. Semiparametric Estimation of the Binary Choice Model for Contingent Valuation. *Land Economics* 72 (4): 462-73.

Manski C.F. 1975. Maximum Score Estimation of the Stochastic Utility Model of Choice. *Journal of Econometrics* (3): 205-28.

Mendelsohn R. 1999. Framework for the valuation of AnGR. In: Rege J.E.O. (ed), *Economic valuation of animal genetic resources. Proceedings of an FAO/ILRI Workshop held at FAO Headquarters, Rome, Italy, 15-17 March 1999.* ILRI (International Livestock Research Institute), Nairobi, Kenya. 77 pp.

Mitchell R.C. and Carson R.T. 1981. *An Experiment in Determining Willingness to Pay for National Water Quality Improvements.* Draft Report to the U.S. Environmental Protection Agency, Office of Policy Analysis. Resources for the Future, Washington, D.C., USA.

Mitchell R.C. and Carson R.T. 1989. *Using Surveys to Value Public Goods: the Contingent Valuation Method.* Resources for the Future, Washington, D.C., USA.

Mitchell G., Smith C., Makower M. and Bird P.J.W.N. 1982. An Economic Appraisal of Pig Improvement in Great Britain. *Animal Production* 35: 215-24.

Pindyck R. 1991. Irreversibility, Uncertainty, and Investment. *Journal of Economic Literature* 29.

Scarpa R. 1999. Revealed preference valuation methods for farm animal genetic material: Principles, strengths and weaknesses. In: Rege J.E.O. (ed), *Economic valuation of animal genetic resources. Proceedings of an FAO/ILRI workshop held at FAO Headquarters, Rome, Italy, 15-17 March 1999.* ILRI (International Livestock Research Institute), Nairobi, Kenya. 77 pp.

Staniswalis J.G. and Cooper V. 1988. Kernel Estimates of Dose-Response. *Biometrics* 44: 1103-19.

Swanson T. 1996. The Management of Genetic Resources for Agriculture: Ecology and Information, Externalities and Policies. Paper presented at the XXIII Meeting of International Association of Agricultural Economists, Sacramento, CA. August 1997.

Swanson T. 1998. The Source of Genetic Resource Values and the Reasons for Their Management. In: Evenson R.E., Gollin D. and Santaniello V. (eds), *Agricultural Values of Plant Genetic Resources.* CAB International, Wallingford, UK. pp. 67-81.

U.S. Department of Commerce, National Oceanic and Atmospheric Administration. 1993. Natural Resource Damage Assessment under the Oil Pollution Act of 1990. *Federal Register* 58 (10): 4601-14.

Framework for the economic valuation of AnGR

R. Mendelsohn
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Four major values

Increase demand for animal products

1. Increase quality
    - reduce fat
    - better taste
    - dependable quality.
2. Segmented market
    - brand cheese
    - regional specialty
    - successful marketing
3. Valuation methods
    - hedonic pricing
    - demand analysis.

Increase farm animal productivity

1. Faster growth
    - higher growth per day
    - more growth per input.
2. More offspring
3. Less disease
4. Methods
    - farm economic model
    - supply model.

Input to creation of future animals

1. Breed stock
2. Gene
3. Valuation method
    - valuation of breeding programme
    - farm economic model

Aesthetic value

1. Existence value
    - cultural nonmarket
2. Recreation value
    - animal fairs
    - tourism
3. Environmental value
    - location specific
    - pollution
    - cropping effects
4. Methods
    - survey - contingent valuation

Why value AnGR?

1. Guide genetic improvement programmes
    - what attributes should be improved?
    - what is the magnitude of the benefits of programmes?
2. Conservation
    - how to rank species-breeds?
    - how much to spend on conservation?
    - who benefits from conservation and what will they pay?
3. Trading
    - what price to set for a breed?
    - who gets benefits?

4. Policy
    - how much conservation will effective market support?
    - how much conservation must be supported by public means because of non-market concerns?

What is the AnGR problem?

1. Market failure
    - no property rights in breeds
    - no property rights in genetic material
    - market undervalues genetics.
2. Non-market services
    - environment
    - cultural
    - market undervalues these services.
3. Hypothesis
    - property rights problem is global
    - non-market service problem is local.

FAO Plan of Action

1. Market failure
    - study why markets for AnGR may have failed: e.g. absence of property rights
    - explore alternative institutions to create new property rights
    - determine consequences of alternatives.
2. Policy interactions
    - determine which policy actions have effects on AnGR: e.g. subsidies for exotics, intensive agriculture, feed grains, trade barriers
    - explore policy alternatives to reduce negative impacts on AnGR.
3. Explore using values to manage AnGR
    - develop management guidelines for countries
    - encourage countries to develop management examples
    - communicate values.

Guiding principles

1. Whereas AnGR management should consider all consequences of choices, valuation helps identify which consequences are most important
2. Most values depend on context. They will vary with the market, region, ecosystem, and production system being considered
3. Analysis must consider not only immediate economic gains but long term
4. Analysis must consider economic and non-market effects as well
5. Valuation should be open and transparent and include all relevant parties.

Report on the state of the world

1. It is premature for formal quantitative country valuations
2. Countries could be asked what they would like to be valued.

Valuation of animal genetic resources

An ILRI–FAO planning workshop

15–17 March 1999

FAO Headquarters, Rome

Canada Room A-356

Developing the Schedule of Activity, with Proposed Presenters

(Working discussion Session to follow each Briefing)

Rapporteurs: Richard Laing and Robert Mendelsohn

0840h Registration – Canada Room
0900h Welcome

Sequence of Workshop Briefings

- *Economic Applications in Animal Genetics and Breeding* – **Joel Weller, Israel**
- *Why Value AnGR?* – **Ed Rege, ILRI**
- *Review of AnGR Valuation Work to Date* – **Gustavo Gandini, Italy**
- *Genetic Resource Valuation Methodologies, their Strengths and Weaknesses in Application* – (to **be split amongst 3 experts: Robert Mendelsohn, USA; Donato Romano, Italy; and Ricardo Scarpa, Italy)**
- *Pertinent Aspects of the Global Strategy for the Management of Animal Genetic Resources* – **Keith Hammond, FAO**

Working Discussions

- *Inter-relationships between the Valuation of AnGR and Institutional Frameworks within Country and Internationally*
- *What Data Should Countries be Collecting When Preparing Their State of the World's AnGR to Enable Valuation Studies ?*

Future Directions – Developing Methodologies for Assessment

- *Developing Guidelines for Country Use*
- *Recommended Work Plans for ILRI and FAO*

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